PHASE 2
DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Glossary and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Program
ANFO	Ammonium Nitrate Fuel Oil
AWR	All Weather Road
BMP	Best Management Practices
cm	centimetre
CCME	Canadian Council of Ministers of the Environment
CEAA	Canadian Environmental Assessment Agency
CWP	Contact Water Pond
DFO	Fisheries and Oceans Canada
EAA	Existing and Approved Authorizations
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
GN-DOE	Government of Nunavut, Department of Environment
INAC	Indigenous and Northern Affairs Canada
ISQG	Interim Sediment Quality Guidelines
KIA	Kitikmeot Inuit Association
km	kilometre
LSA	Local Study Area
m	metre
m^2	square metres
m^3	cubic metres
mg/kg	milligram per kilogram
ML ARD	Metal Leaching Acid Rock Drainage
MMER	Metal Mining Effluent Regulations
NIRB	Nunavut Impact Review Board

NSA	Nunavut Settlement Area
NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
OHF	Oil Handing Facilities
PAH	Polycyclic Aromatic Hydrocarbons
PDA	Project Development Area
PEL	Probable Effects Level
Project	The Phase 2 Project
RSA	Regional Study Area
TBT	Tributyltin
TIA	Tailings Impoundment Area
TK	Traditional Knowledge
TMA	Tailings Management Area
TMAC	TMAC Resources Inc.
TOC	Total Organic Carbon
tpd	Tonnes Per Day
TSS	Total Suspended Solids
QA/QC	Quality Assurance and Quality Control
VEC	Valued Ecosystem Component
WTP	Water Treatment Plant
WRR	Winter Road Route
yr	Year

5. Freshwater Sediment Quality

Freshwater sediment quality has been identified as a Valued Ecosystem Component (VEC) for Phase 2 as the project has the potential to interact with the freshwater environment through infrastructure development, runoff, dust deposition, or the discharge of water. Freshwater sediments are important because they serve as a habitat for benthic organisms, which are key components of aquatic food webs, and play an important role in nutrient and metal biogeochemical cycling. Sediment quality is an aggregate definition that encompasses a complex suite of parameters and indicators that describe the sediment environment and its ability to sustain ecological and biogeochemical functions.

Phase 2 activities may introduce chemical constituents that affect sediment quality by increasing the concentrations of metals, nutrients, organic matter, and pollutants in sediments. The potential effects of Phase 2 on freshwater sediment quality include physical disturbances to sediments from site preparation, construction, and decommissioning activities; inputs of nutrients and pollutants from the use of explosives, fuels, and oils; inputs of metals, nutrients, and pollutants from dust deposition; and exposure to discharges of treated sewage or wastewater containing site or mine contact water. The Phase 2 Project will minimize or eliminate potential adverse changes to sediments through mitigation and management efforts such as erosion and runoff control measures and adherence to effective best management practices (BMP).

This chapter presents the existing conditions of the freshwater sediment quality as it relates to the proposed Phase 2 Project and identifies and evaluates the potential Project-related effects and cumulative effects within a local and regional context.

5.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

5.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (Banci and Spicker 2016) was reviewed for information related to freshwater sediment quality. There were no direct references relevant to the existing freshwater sediment quality in the NTKP report.

5.1.2 Incorporation of Traditional Knowledge for Valued Ecosystem Component Selection

The NTKP report made no direct reference to freshwater sediment quality (Banci and Spicker 2016). Inuit value the integrity of the environment, and noted the general importance of water quality, benthic invertebrates, fish communities, and fish habitat, all of which are directly affected by or dependent upon sediment quality. Therefore, the importance of freshwater sediment quality as a facet of environmental quality was considered in the selection of freshwater sediment quality as a VEC.

5.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the NTKP report were considered when developing the spatial and temporal boundaries for the Phase 2 Project. The NTKP report showed that specific and general fishing locations extend along both shores of Melville Sound, but are concentrated along the southern shore extending both east and west of Roberts Bay. General fishing areas also extend inland along the entire length of the Hope

Bay Greenstone Belt. Sediment quality is an important component in determining the quality of fish habitat. Therefore, the entire Hope Bay Development area was included within the spatial boundaries of the assessment of freshwater sediment quality.

5.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the NTKP report were considered when developing the effects assessment for freshwater sediment quality. No specific references relevant to the effects assessment for sediment quality were included in the NTKP report.

5.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The NTKP report was considered when developing mitigation and adaptive management plans for freshwater sediment quality. No specific references to mitigation and adaptive management measures relevant to sediment quality were included in the NTKP report.

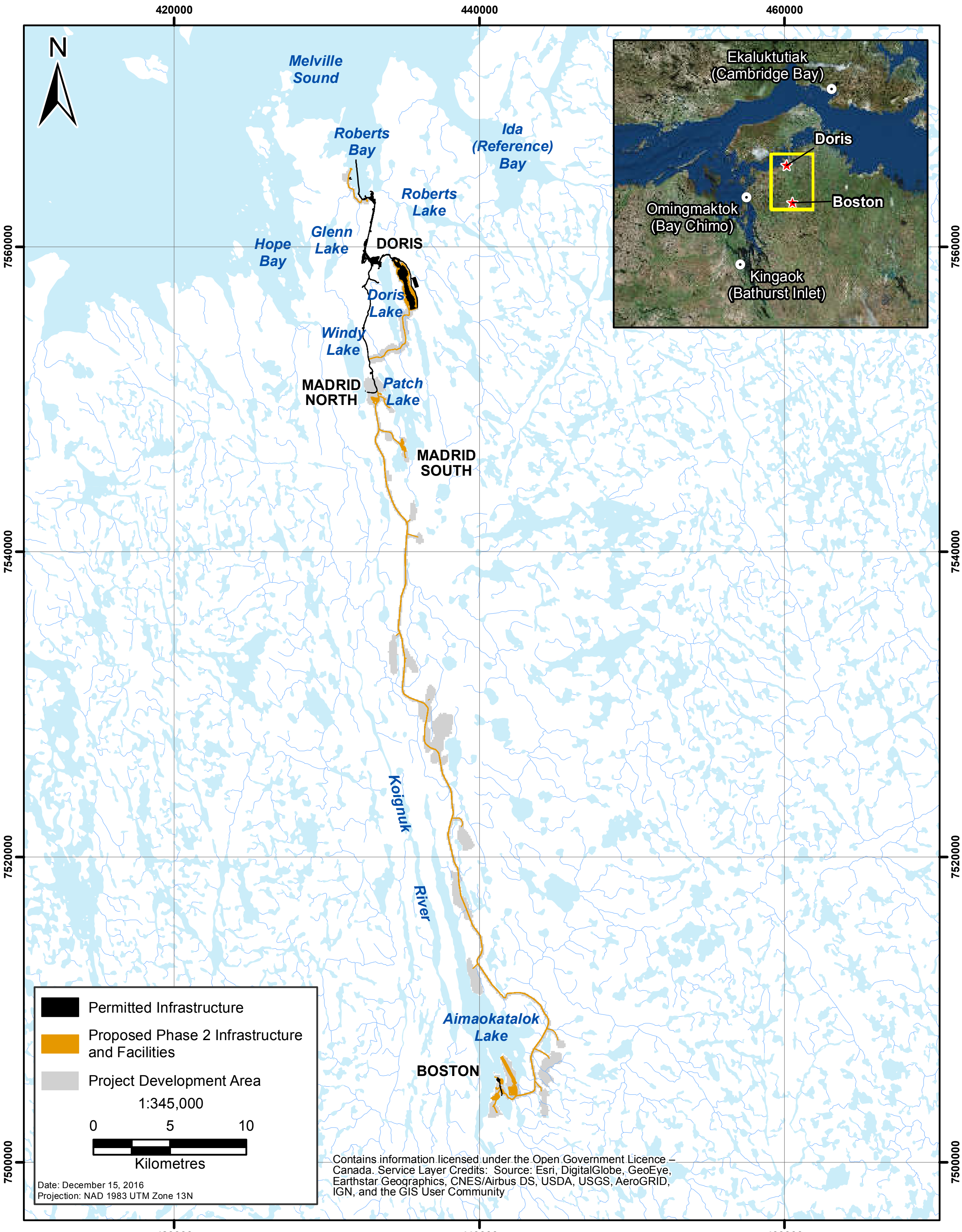
5.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

Phase 2 of the Hope Bay Project is situated within the Queen Maud Gulf Lowlands, approximately 153 km southwest of Cambridge Bay on the southern shore of Melville Sound in the West Kitikmeot region of Nunavut (Figure 5.2-1). The property contains a greenstone belt running 80 km in a north-south direction that varies in width between 7 km and 20 km. The Hope Bay Project consists of three developments, with Doris being the northernmost, followed by Madrid in the north-central area, and Boston at the southern end (Figure 5.2-1).

Baseline freshwater information has been collected within the greenstone belt since the early 1990s. The proposed Phase 2 infrastructure in each mining district lies within a single defined Local Study Area (LSA) that is bounded by a larger Regional Study Area (RSA; see Section 5.4; Figure 5.2-2). Regionally, the Phase 2 Project lies entirely within the Southern Arctic Ecozone and is situated in an area of continuous permafrost. Generally, Doris has more variable relief, with exposed igneous extrusions to 160 m, and a greater marine influence than Madrid or Boston, which are characterized by flat rolling bedrock covered by thin layers of moraine, lacustrine, and fluvial deposits.

Winter is characterized by extreme cold, with mean monthly temperatures ranging from -33.4ºC to -3.1ºC, and the coldest temperatures occurring in January and February. There is a short snow-free season (mid-June through September) with mean monthly temperatures ranging from -2.5ºC to 13.9ºC; the warmest temperatures are typically recorded in July (see Volume 4, Section 1). The Doris meteorological station reports total summer rainfall (June to September) ranging from 47.8 mm (2012) to 97.8 mm (2011; Volume 4, Section 1). The region's vegetation is characterized by shrub tundra vegetation such as dwarf birch (*Betula nana*), willow (*Salix* sp.), Labrador tea (*Ledum decumbens*), avens (*Dryas* sp.), and blueberries (*Vaccinium* sp.) (Rescan 2011b).

Figure 5.2-1
Project Location



The freshwater LSA includes the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds in the north, and the Aimaokatalok and East watersheds in the south (Figure 5.2-2). Water from the northern Doris and central Madrid watersheds flows northward into Roberts Bay via Little Roberts Outflow and Glenn Outflow, while water from the southern Boston watersheds flows into Hope Bay via the large Koignuk River system. The largest lakes in the north and central belt include Doris, Windy, Patch, Glenn, and Ogama lakes, with Aimaokatalok Lake being the largest lake in the southern belt. The hydrology in the Phase 2 area is dominated by snowmelt, with peak flows occurring in June in most watersheds. The lakes are typically frozen from October to June with ice thickness ranging between 1.5 to 2.0 m (Appendices V5-3I and V5-3J). Winter flow is largely absent because of negligible groundwater reserves outside of the permafrost and the lack of unfrozen surface water. Due to the influences of climate and permafrost, there is one major flood period (freshet) in June that quickly recedes into summer, with the hydrograph being punctuated with occasional high–flow events from storms during the open-water season.

The following section provides a summary of the methods and results from the freshwater sediment quality sampling carried out in the Phase 2 Project area and surrounding region. Monitoring for sedimentation rates or the modelling of sediment dispersion has not been conducted for the Phase 2 Project as it has been deemed unnecessary based on potential Phase 2 activities in or near freshwater environments. Phase 2 activities are expected to interact with freshwater sediments on local scales over short durations. These localized, short-term effects are expected to be effectively mitigated and managed, as detailed in the relevant management plans provided in Section 5.5.3.2.

5.2.1 Regulatory Framework

There are several acts, regulations, and guidelines relevant to the management and preservation of freshwater sediment quality. Table 5.2-1 lists and provides a brief description of the key acts and regulations pertaining to freshwater sediment quality.

In addition to these acts and regulations, the protection of freshwater sediment quality is also guided by the *Canadian Environmental Quality Guidelines* (CCME 2001b) which include the *Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 2016) published by the Canadian Council of Ministers of the Environment (CCME). These sediment quality guidelines define concentrations of sediment quality parameters that should present a negligible risk to aquatic organisms.

5.2.2 Data Sources

The primary sources of sediment quality data used to describe the existing environment in lakes, streams, and rivers of the LSA and RSA are the baseline studies conducted in 2007, 2009, and 2010, and the Aquatic Effects Monitoring Program (AEMP) for the Doris Project conducted from 2010 to 2015. Sediment quality data have also been collected historically (1993, 1996, 1997, 2002) within the Project LSA and RSA. Several activities associated with the permitted Doris Project began in 2007. Although the Doris AEMP has shown that there have been no effects of the Doris Project on the freshwater environment, data collected in the years prior to 2007 are considered representative of baseline conditions, while data collected from 2007 onward are considered representative of existing conditions.

Figure 5.2-2
Freshwater Sediment Quality Local and Regional Study Areas

TMAC RESOURCES

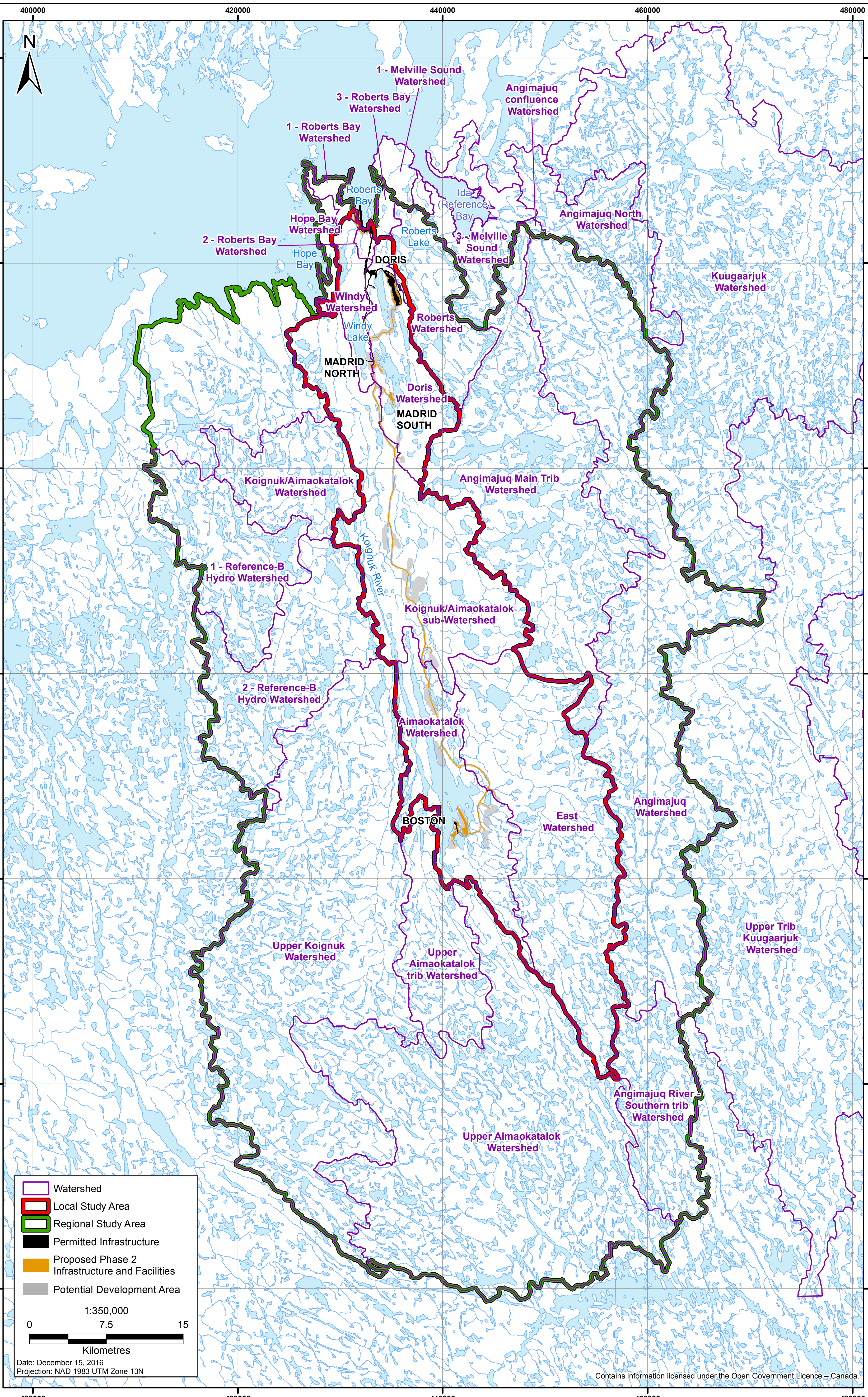


Table 5.2-1. Federal and Territorial Acts and Regulations Relevant to Freshwater Sediment Quality

Name of Act	Year (Year of Most Recent Amendment)	Administered by	Relevant Regulations under the Act	Description/Purpose
Arctic Waters Pollution Prevention Act	1985 (2014)	Indigenous and Northern Affairs Canada (INAC)	Arctic Waters Pollution Prevention Regulations	• Prohibits the deposit of waste in Arctic waters unless authorized under the *Canada Water Act*, and describes limits of liability.
Canada Water Act	1985 (2014)	Environment and Climate Change Canada (ECCC)		• Provides a framework for the management of water resources in Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources. • Establishes federal-provincial arrangement for the management of water resources.
Fisheries Act	1985 (2016)	Fisheries and Oceans Canada (DFO) ECCC	Metal Mining Effluent Regulations	• Protects fish habitat by prohibiting any harmful alteration, disruption, or destruction of fish habitat. • Prohibits the deposition of deleterious substances into waters frequented by fish, unless authorization is granted.
Canadian Environmental Protection Act	1999 (2016)	ECCC		• Deals with the prevention of pollution and the protection of the environment and human health from toxic substances, with the goal of contributing to sustainable development. • Regulates many substances that have a deleterious effect on the environment.
Nunavut Waters and Nunavut Surface Rights Tribunal Act	2002 (2016)	INAC NWB	Nunavut Waters Regulations	• Established the Nunavut Water Board (NWB). • Nunavut Waters Regulations: Establishes licensing criteria for use of waters and for deposit of waste for mining undertaking.
Environmental Protection Act	1988 (1999)	Government of Nunavut, Department of Environment (GN-DOE)		• Prohibits the discharge of contaminants into the environment without authorization.
Environmental Rights Act	1988 (2011)	GN-DOE		• Grants all residents the ability to launch an investigation into the release of a contaminant into the environment.

Baseline data are available in the following reports:

- Boston Property N.W.T.: Environmental Data Report (Rescan 1994; Appendix V5-3B);

- Hope Bay Belt Project: Environmental Baseline Studies Report 1996 (Rescan 1997; Appendix V5-4C);
- Hope Bay Belt Project: 1997 Environmental Data Report (Rescan 1998; Appendix V5-4D);
- Doris North Project Aquatic Studies 2002 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003; Appendix V5-5A);
- Boston and Madrid Project Areas 2006 – 2007 Aquatic Studies (Golder Associates Ltd. 2008; Appendix V5-3G);
- 2009 Freshwater Baseline Report, Hope Bay Belt Project (Rescan 2010; Appendix V5-3I);
- Hope Bay Belt Project: 2010 Freshwater Baseline Report (Rescan 2011c; Appendix V5-3J);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report (Rescan 2011a);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report (Rescan 2012);
- Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report (Rescan 2013);
- Doris North Project: 2013 Aquatic Effects Monitoring Program Report (ERM Rescan 2014); and
- Doris North Project: 2014 Aquatic Effects Monitoring Program (ERM 2015a); and
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016).

The Doris North Project Aquatic Effects Monitoring Program reports are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca).

5.2.3 Methods

5.2.3.1 Lakes

Between 1993 and 2015, sediment quality samples were collected from 12 lakes in the LSA, with nine in the North Belt (Figure 5.2-3) and three in the South Belt (Figure 5.2-4). Eight lakes were also sampled for sediment quality throughout the RSA (Figures 5.2-3 and 5.2-4). Sampling efforts focussed on lakes near existing and proposed infrastructure within the LSA, and at reference sites or far-field (downstream) sites in the RSA. Multiple sites and/or depths were often sampled at many of the largest lakes including Doris, Patch, Windy, Glenn, and Aimaokatalok within the LSA; and Reference Lake A and Reference Lake B in the RSA (Figures 5.2-3 and 5.2-4). A summary of the lake sediment quality sampling programs undertaken between 2007 and 2015, including sampling locations and replication, is shown in Table 5.2-2.

Lake sediment quality samples were collected using an Ekman dredge (2007 to 2015) or a Wildco gravity corer (2007 only), with one to five replicate samples collected at each site. The top few centimetres of each sediment sample was subsampled and stored in clean plastic bags, and sent to Maxxam Analytics Inc. (Burnaby, BC; 2007) or ALS Environmental (Vancouver or Burnaby, BC; 2009 to 2015) for analysis of physical and chemical properties. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 5.2.2.

For the characterization of existing conditions, data were grouped by depth strata since sediments in the shallow near-shore areas tend to be coarser than deeper, calmer areas where finer materials settle, and fine-grain sediments tend to be associated with higher metal and organic carbon concentrations. Sample depths of 0 to 10 m were considered ‘shallow’ sites, and sample depths greater than 10 m were considered ‘deep’ sites.

Figure 5.2-3
Historical Freshwater Sediment Sampling Locations in the North Belt LSA and RSA, 1996 to 2015

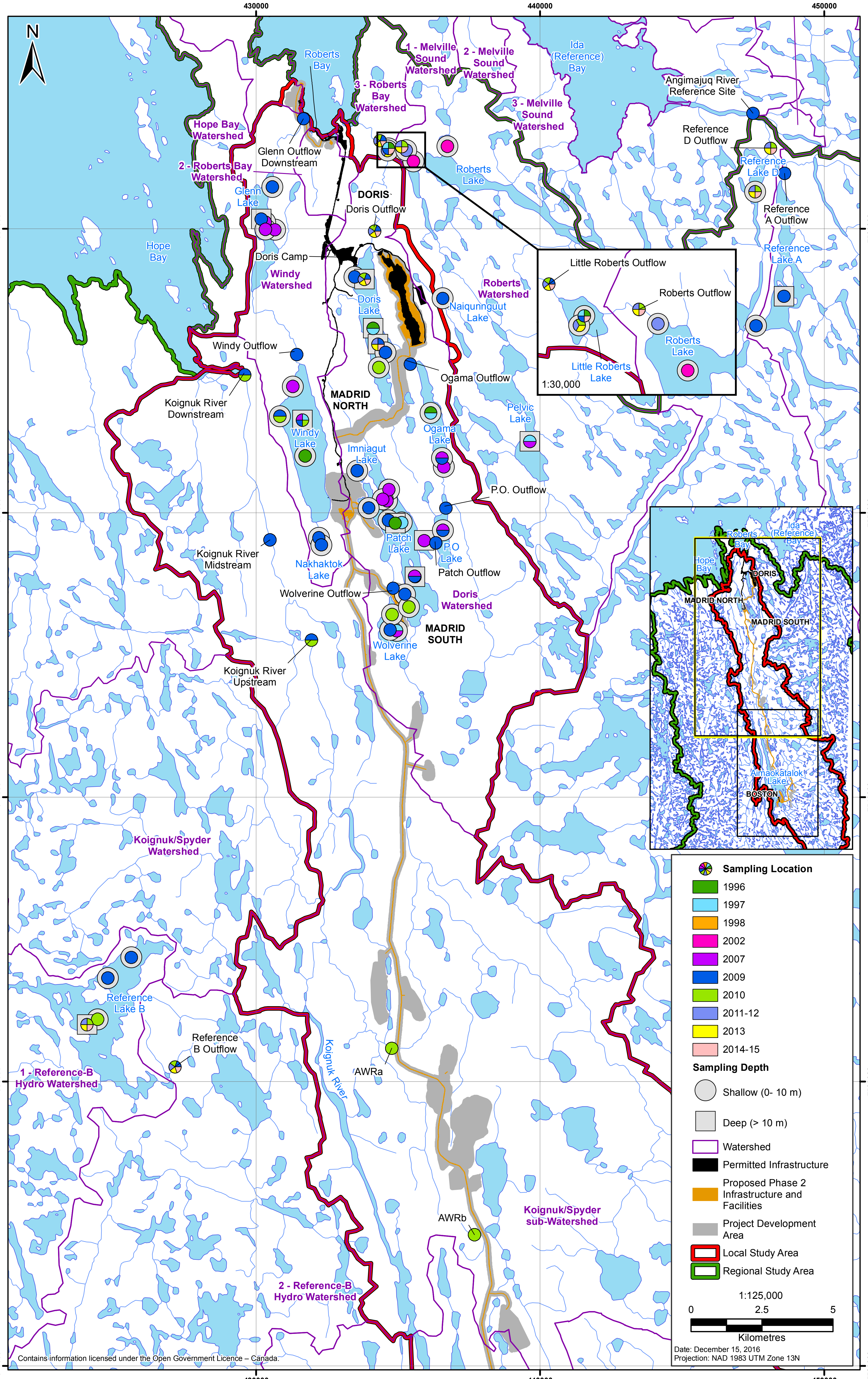


Figure 5.2-4
Historical Freshwater Sediment Sampling Locations in the South Belt LSA and RSA, 1993 to 2015

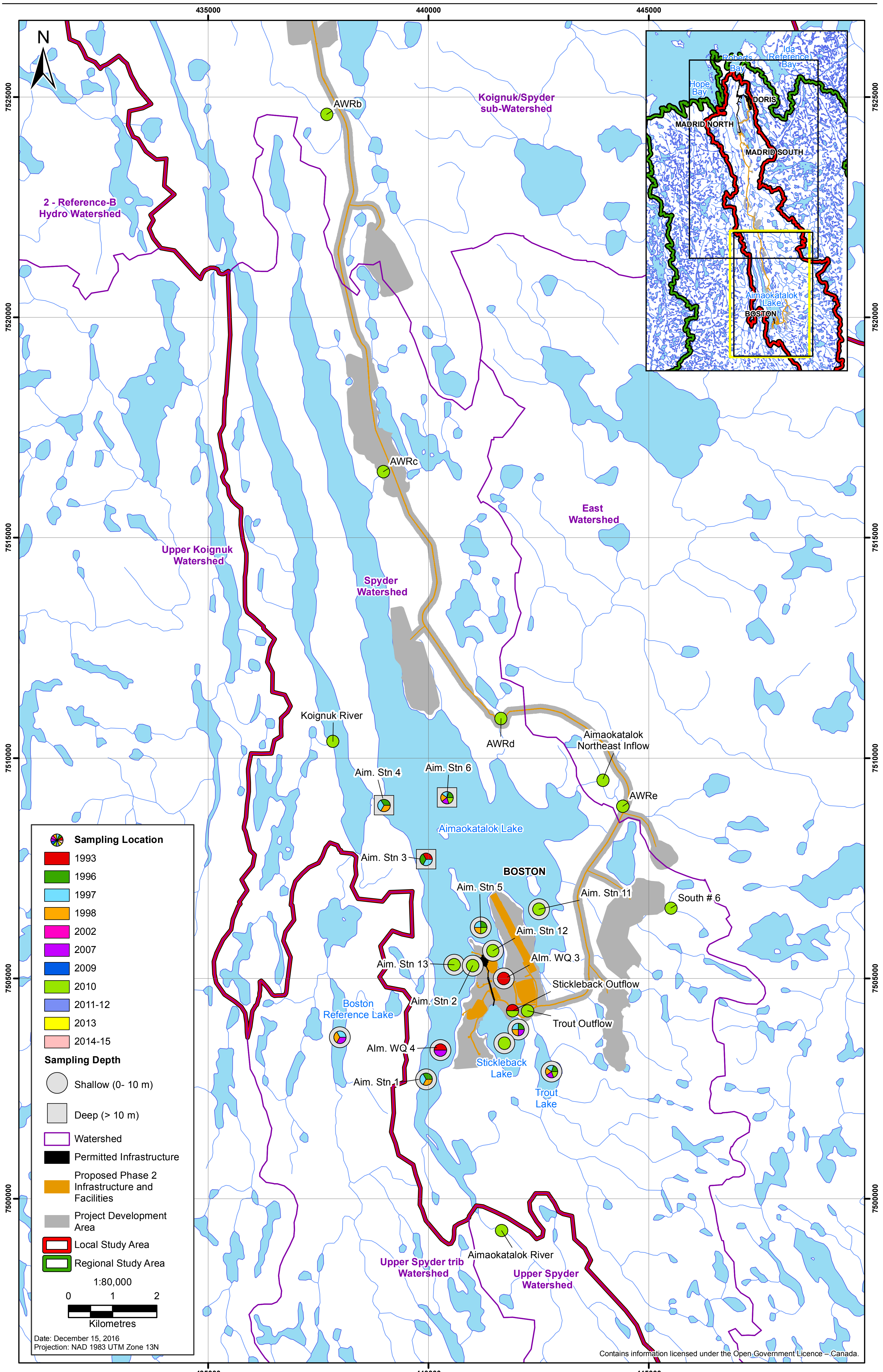


Table 5.2-2. Summary of Lake Sediment Sampling Conducted in the LSA and RSA, 2007 to 2015

Year	2007	2009	2010	2011 and 2012	2013 to 2015
Month Sampled	August	August	August	August	August
Sampling Equipment	gravity corer Ekman	Ekman	Ekman	Ekman	Ekman
Sediment Quality Parameters	Particle size, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals
LSA	<u>North Belt</u> Ogama Patch Wolverine P.O. Windy Glenn <u>South Belt</u> Aimaokatalok Stickleback Trout	<u>North Belt</u> Doris Ogama Patch Wolverine P.O. Nakhaktok Imniagut Windy Glenn	<u>North Belt</u> Doris Patch Wolverine Windy <u>South Belt</u> Aimaokatalok Stickleback Trout	<u>North Belt</u> Doris	<u>North Belt</u> Doris
RSA	Pelvic Boston Reference	Little Roberts Naiqunnguut Reference A Reference B	Little Roberts Reference B Reference D	Roberts Little Roberts Reference B Reference D	Little Roberts Reference B Reference D
Site Replication	n = 5 (gravity corer) n = 1 (Ekman)	n = 3	n = 3	n = 3	n = 3

5.2.3.2 Streams and Rivers

Sediment quality samples were collected from 16 streams and rivers in the LSA and seven streams and rivers throughout the RSA from 1993 to 2015 (Figures 5.2-3 and 5.2-4). Sampling efforts focussed on streams and rivers near existing and proposed infrastructure within the LSA, and at reference sites or far-field (downstream) sites in the RSA. The Koignuk River was sampled upstream in the South Belt LSA and downstream in the North Belt LSA (Figures 5.2-3 and 5.2-4). A summary of the sampling programs undertaken between 2009 and 2015 (there were no stream or river sediment samples collected in either 2007 or 2008), including sampling locations and replication, is shown in Table 5.2-3.

From 2009 to 2015, stream and river sediment quality samples were typically collected using a plastic spoon and bowl. Three replicate samples were collected at each site, with each replicate consisting of several spoonfuls of sediments, with replicates collected three times the channel widths apart whenever possible. The sediments were carefully drained of excess water, homogenized, and transferred into Whirl-Pak bags. An Ekman dredge was used occasionally (as described for lake sediment sampling) if the site consisted of fine-grained material or was too deep or fast flowing to sample using the spoon method. The samples were kept cool until shipment to ALS Environmental (Vancouver or Burnaby, BC) where the sediments were analyzed for particle size, nutrients, total organic carbon (TOC), and metals content. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 5.2.2.

Table 5.2-3. Summary of Stream Sediment Sampling Conducted from 2009 to 2015

Year	2009	2010	2011 to 2015
Month Sampled	August	August	August
Sampling Equipment	Grab samples	Grab samples	Grab samples
Sediment Quality Parameters	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals
LSA	North Belt	North Belt	North Belt
	Doris OF	Doris OF	Doris OF
	Ogama OF	AWRa	
	Patch OF	AWRb	
	P.O. OF	Koignuk River	
	Windy OF	South Belt	
	Glenn OF	Stickleback OF	
	Koignuk River	Trout OF	
		Koignuk River	
		Aimaokatalok NE IF	
		S6	
		AWRc	
		AWRd	
		AWRe	
RSA	Little Roberts OF	Little Roberts OF	Little Roberts OF
	Reference A OF	Roberts OF	Roberts OF
	Reference B OF	Reference B OF	Reference B OF
	Angimajug River	Reference D OF	Reference D OF
		Aimaokatalok River	
Site Replication	n = 3	n = 3	n = 3

Note: OF = outflow, IF = inflow

5.2.3.3 Quality Assurance and Quality Control

The lake, stream, and river sediment sampling quality assurance and quality control (QA/QC) program included the use of chain of custody forms and the collection of replicate sediment samples to account for within-site variability.

5.2.3.4 Calculation of Summary Statistics

Summary statistics were calculated for sediment quality parameters within the LSA (North Belt and South Belt) and the RSA. The North Belt LSA contains the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds and the South Belt LSA contains the Aimaokatalok and East watersheds (Figure 5.2-2).

For the calculation of minimum, maximum, mean, median, and the 75th and 95th percentile values for sediment quality parameters, one half of the value of the detection limit was substituted for sample concentrations that were below analytical detection limits. The minimum value represents the lowest value reported for any replicate after substituting one half of the detection limit for values that were below detection limits. The maximum value represents the highest detectable concentration in any replicate and excludes values reported as being below analytical detection limits (except when all values were below detection limits, in which case the maximum represents the highest detection limit). Sediment quality data collected on the same date from the same site (replicates) were averaged prior to the calculation of the mean, median, and the 75th and 95th percentiles to give equal weighting to samples regardless of the degree of replication. Whenever the value of the minimum, maximum, mean, median, or percentile was a censored value (i.e., sample concentration below the analytical detection limit), this value was reverted back from one half of the detection limit to its raw form (i.e., reported as being less than '<' the given detection limit) to clearly distinguish censored values.

5.2.4 Characterization of Existing Conditions

Many aquatic organisms live in or on the sediments (benthic organisms or benthos), and these organisms are potential prey items for higher trophic level consumers. The CCME has established interim guidelines for sediment quality parameters to monitor and protect freshwater life from acute and chronic toxicity. The CCME guidelines are conservative empirical thresholds that are meant to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 1995).

A summary of particle size and sediment quality results from the lake, stream, and river sampling program in the LSA (North Belt and South Belt) and RSA is presented below. The discussion is focussed on data collected from 2007 to 2015. These data are discussed within the framework of CCME sediment quality guidelines where applicable (CCME 2016).

5.2.4.1 Lakes

<u>Sediment Composition</u>

The particle size composition of sediments is important for determining the type and variety of benthic organisms, and estimating the metal adsorption potential and organic carbon content of the sediments. Finer sediments composed of silt and clay tend to have greater concentrations of organic carbon and metals and may host different types of benthic organisms compared to coarser sediments.

Lake sediments collected from the LSA and RSA were mainly comprised of fine material, with mean silt and clay contents ranging from 73% in shallow sampling sites (0 to 10 m depth) to 99% in deep sites (> 10 m depth; Table 5.2-4). Shallower areas typically contained more sand and less clay than deeper areas. The mean gravel content was low in all study areas (≤ 1%; Table 5.2-4).

Table 5.2-4. Summary of Lake Sediment Composition in the LSA and RSA, 2007 to 2015

LSA - North Belt	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Shallow Sites	**n = 51**	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 51**
Gravel >2 mm (%)	<0.1	0.7	<1.0	0.7	1.6	4.0
Sand 2.0 mm - 0.063 mm (%)	1.0	24	5.9	32	85	91
Silt 0.063 mm - 4 µm (%)	5.0	46	51	58	68	76
Clay <4 µm (%)	2.0	30	30	39	57	64
Deep Sites	**n = 51**	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 51**
Gravel >2 mm (%)	<0.1	0.3	<0.1	<1.0	0.7	4.0
Sand 2.0 mm - 0.063 mm (%)	0.2	0.9	0.8	1.3	1.8	3.3
Silt 0.063 mm - 4 µm (%)	24	54	50	61	78	91
Clay <4 µm (%)	8.0	45	48	50	64	76

LSA - South Belt	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
Shallow Sites	**n = 21**	**n = 7**	**n = 7**	**n = 7**	**n = 7**	**n = 21**
Gravel >2 mm (%)	<0.1	1.0	<0.1	0.2	4.4	17
Sand 2.0 mm - 0.063 mm (%)	0.6	27	38	42	52	71
Silt 0.063 mm - 4 µm (%)	26	54	57	61	71	88
Clay <4 µm (%)	0.3	19	18	30	41	49
Deep Sites	**n = 3**	**n = 1**	**n = 1**	**n = 1**	**n = 1**	**n = 3**
Gravel >2 mm (%)	<1.0	all concentrations below detection limits				<1.0
Sand 2.0 mm - 0.063 mm (%)	7.4	8.8	8.8	8.8	8.8	11
Silt 0.063 mm - 4 µm (%)	43	44	44	44	44	45
Clay <4 µm (%)	46	47	47	47	47	49
RSA	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
Shallow Sites	**n = 60**	**n = 20**	**n = 20**	**n = 20**	**n = 20**	**n = 60**
Gravel >2 mm (%)	<0.1	0.2	<0.1	0.3	0.6	4.0
Sand 2.0 mm - 0.063 mm (%)	0.2	12	7.6	13	43	74
Silt 0.063 mm - 4 µm (%)	21	67	70	78	86	95
Clay <4 µm (%)	2.5	20	19	23	39	64
Deep Sites	**n = 21**	**n = 7**	**n = 7**	**n = 7**	**n = 7**	**n = 21**
Gravel >2 mm (%)	<0.1	0.5	<1.0	0.7	0.9	2.4
Sand 2.0 mm - 0.063 mm (%)	1.0	10	10	12	17	24
Silt 0.063 mm - 4 µm (%)	45	57	59	59	63	67
Clay <4 µm (%)	9.5	33	32	36	44	53

Notes:
n = number of observations.
<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits. The only exception was when all values were below detection limits, in which case the maximum represents the highest detection limit.

Total Organic Carbon and Nutrients

Mean TOC content ranged from 1.6 to 3.2% in the shallow sites of the LSA and RSA, and from 0.5 to 2.1% in the deep sites (Table 5.2-5). The pooled data from all samples indicated that TOC content was positively correlated with silt content ($r = 0.59$, $p < 0.001$, $n = 69$) and negatively correlated with sand content ($r = -0.54$, $p < 0.001$, $n = 69$; Pearson's correlations of logit transformed percentage data).

Concentrations of plant available nitrate and nitrite were generally near or below detection limits in lakes of the LSA and RSA. Available ammonium concentrations were highest in the South Belt LSA sediments, and available phosphate concentrations were variable among sites and sampling depths (Table 5.2-5).

Table 5.2-5. Summary of Lake Sediment Total Organic Carbon and Nutrient Concentrations in the LSA and RSA, 2007 to 2015

LSA - North Belt	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Shallow Sites	**n = 84**	**n = 30**	**n = 30**	**n = 30**	**n = 30**	**n = 84**
Total Organic Carbon (%)	0.05	1.6	0.6	2.1	6.7	8.9
	n = 51	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 51**
Available Ammonium (as N) (mg/kg)	1.2	19.5	9.6	17.5	67.6	117
Available Nitrate (as N) (mg/kg)	<2	1.7	1.3	2.4	3.1	3.9
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1.7
Available Phosphate (as P) (mg/kg)	<2	5.6	4.6	5.6	12.1	51.8
Deep Sites	**n = 63**	**n = 20**	**n = 20**	**n = 20**	**n = 20**	**n = 63**
Total Organic Carbon (%)	0.07	2.1	2.8	3.0	3.1	3.3
	n = 51	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 51**
Available Ammonium (as N) (mg/kg)	1.74	24.3	29.2	30.4	42.5	74.5
Available Nitrate (as N) (mg/kg)	<2	1.7	<4	<4	2.2	2.9
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1
Available Phosphate (as P) (mg/kg)	<2	4.1	3.0	3.9	11.7	20.6
LSA - South Belt	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
Shallow Sites	**n = 34**	**n = 12**	**n = 12**	**n = 12**	**n = 12**	**n = 34**
Total Organic Carbon (%)	0.04	2.1	0.6	1.0	9.2	18.4
	n = 21	**n = 7**	**n = 7**	**n = 7**	**n = 7**	**n = 21**
Available Ammonium (as N) (mg/kg)	<0.8	8.6	6.9	10.1	22.8	33.6
Available Nitrate (as N) (mg/kg)	<2	all concentrations below detection limits				<5
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1
Available Phosphate (as P) (mg/kg)	<2	4.4	3.9	4.4	8.2	11.7
Deep Sites	**n = 9**	**n = 3**	**n = 3**	**n = 3**	**n = 3**	**n = 9**
Total Organic Carbon (%)	0.08	0.5	0.1	0.7	1.2	1.6
	n = 3	**n = 1**	**n = 1**	**n = 3**	**n = 3**	**n = 34**
Available Ammonium (as N) (mg/kg)	5.8	7.2	7.2	7.2	7.2	8.7
Available Nitrate (as N) (mg/kg)	<5	all concentrations below detection limits				<6
Available Nitrite (as N) (mg/kg)	<1	all concentrations below detection limits				<1.2
Available Phosphate (as P) (mg/kg)	9.4	11.4	11.4	11.4	11.4	15.4
RSA	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
Shallow Sites	**n = 67**	**n = 23**	**n = 23**	**n = 23**	**n = 23**	**n = 67**
Total Organic Carbon (%)	0.13	3.2	3.2	3.9	8.1	11.2
	n = 60	**n = 20**	**n = 20**	**n = 20**	**n = 20**	**n = 60**
Available Ammonium (as N) (mg/kg)	2.29	22.7	21.7	29.8	39.0	80.2
Available Nitrate (as N) (mg/kg)	<2	2.9	<4	<6	5.9	30.3
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<4
Available Phosphate (as P) (mg/kg)	<2	6.9	5.0	7.0	17.7	41.2

RSA	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Deep Sites	**n = 27**	**n = 9**	**n = 9**	**n = 9**	**n = 9**	**n = 27**
Total Organic Carbon (%)	0.14	1.1	0.6	1.0	3.2	5.3
	n = 21	**n = 7**	**n = 7**	**n = 7**	**n = 7**	**n = 21**
Available Ammonium (as N) (mg/kg)	<1.6	5.6	5.2	6.2	10.0	13.2
Available Nitrate (as N) (mg/kg)	<2	all concentrations below detection limits				<6
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1.2
Available Phosphate (as P) (mg/kg)	<2	20.7	8.5	26.6	66.8	124

Notes:
n = number of observations.
<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] *Minimum represents the lowest concentration in any replicate sample.*
[b] *Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles.*
[c] *Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.*

Metals

Mean metal concentrations for lake sediments were examined within the framework of CCME guidelines (CCME 2016). The Interim Sediment Quality Guidelines (ISQG) are conservative empirical thresholds below which no effects on freshwater benthic organisms are predicted to occur. The CCME Probable Effects Level (PEL) thresholds describe the sediment concentration at which biological effects are likely to occur. The concentrations of lake sediment metals of interest in the LSA and RSA as well as the CCME guidelines for these sediment metal concentrations are summarized in Table 5.2-6.

With the exception of copper and mercury concentrations in RSA sediments, mean concentrations of sediment metals were consistently greater at deep depths in the LSA and RSA lakes compared to shallow depths. This corresponds to the higher proportions of silt and clay particles in the sediments collected at deep depths compared to shallow depth. Within each depth class, mean metal concentrations tended to highest in the North Belt LSA compared to the other study areas (Table 5.2-6).

Several metal concentrations were naturally low in the LSA and RSA lake sediments; cadmium, lead, mercury, and zinc concentrations were consistently below CCME ISQG and PEL guideline levels. In contrast, some metals such as chromium were naturally elevated in the LSA and RSA lake sediments. Mean concentrations of chromium in sediments were consistently above the ISQG of 37.3 mg/kg in the deep-water samples, and were frequently greater than the ISQG in the shallow waters (Table 5.2-6). Mean arsenic and copper concentrations were also frequently greater than the ISQGs of 5.9 mg/kg for arsenic and 35.7 mg/kg for copper in sediments of the LSA and RSA lakes (Table 5.2-6). Arsenic concentrations in sediments collected from the southern section of Doris Lake were frequently greater than the PEL of 17 mg/kg (Table 5.2-6).

Table 5.2-6. Summary of Lake Sediment Metals in the LSA and RSA, 2007 to 2015

	CCME Guidelines for the Protection of Aquatic Life[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th percentile[e]	95th percentile[e]	Max[f]		
LSA - North Belt										
Shallow Sites			**n = 84**	**n = 30**	**n = 30**	**n = 30**	**n = 30**	**n = 84**	**n = 30**	**n = 30**
Arsenic	5.9	17	0.980	4.51	3.51	5.13	10.1	18.4	20	0
Cadmium	0.6	3.5	<0.05	0.082	0.080	0.105	0.160	0.190	0	0
Chromium	37.3	90	14.5	57.6	60.7	70.7	76.7	84.8	83	0
Copper	35.7	197	6.40	32.2	30.6	37.9	56.1	60.8	40	0
Lead	35	91.3	2.20	8.46	8.42	10.0	12.7	13.9	0	0
Mercury	0.17	0.49	<0.005	0.0231	<0.050	<0.050	0.0340	0.0676	0	0
Zinc	123	315	15.0	69.3	74.7	85.1	97.2	105	0	0
Deep Sites			**n = 63**	**n = 20**	**n = 20**	**n = 20**	**n = 20**	**n = 63**	**n = 20**	**n = 20**
Arsenic	5.9	17	3.27	11.5	11.6	15.2	20.9	27.2	75	20
Cadmium	0.6	3.5	0.080	0.123	0.120	0.134	0.164	0.180	0	0
Chromium	37.3	90	63.9	73.8	73.9	77.0	80.0	91	100	0
Copper	35.7	197	30.9	40.3	39.8	43.9	48.7	51.1	85	0
Lead	35	91.3	9.40	11.3	11.0	11.6	13.6	15.1	0	0
Mercury	0.17	0.49	0.0168	0.0462	0.0526	0.0589	0.0673	0.0807	0	0
Zinc	123	315	80.9	95.8	96.0	102	106	110	0	0
LSA - South Belt										
Shallow Sites			**n = 34**	**n = 12**	**n = 12**	**n = 12**	**n = 12**	**n = 34**	**n = 12**	**n = 12**
Arsenic	5.9	17	0.558	3.43	2.99	4.57	6.78	13.2	8.3	0
Cadmium	0.6	3.5	<0.05	0.084	0.065	0.120	0.156	0.330	0	0
Chromium	37.3	90	7.6	32.7	37.1	42.6	53.7	64.5	50	0
Copper	35.7	197	2.0	19.9	18.6	26.8	42.9	49.0	25	0
Lead	35	91.3	<2.0	5.13	5.54	6.30	8.51	10.7	0	0
Mercury	0.17	0.49	<0.005	0.0191	0.0238	<0.050	0.0309	0.0434	0	0
Zinc	123	315	9.0	47.8	59.9	62.1	72.5	77.0	0	0

	CCME Guidelines for the Protection of Aquatic Life[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th percentile[e]	95th percentile[e]	Max[f]		
Deep Sites			**n = 9**	**n = 3**	**n = 3**	**n = 3**	**n = 3**	**n = 9**	**n = 3**	**n = 3**
Arsenic	5.9	17	2.40	3.49	3.52	3.54	3.56	4.30	0	0
Cadmium	0.6	3.5	<0.1	0.128	0.157	0.157	0.158	0.260	0	0
Chromium	37.3	90	52.0	60.0	55.6	62.5	68.1	77.7	100	0
Copper	35.7	197	20.4	22.6	23.1	23.1	23.2	25.4	0	0
Lead	35	91.3	7.70	9.17	8.40	9.58	10.5	12.8	0	0
Mercury	0.17	0.49	0.0249	0.0289	<0.050	0.0308	0.0354	0.0435	0	0
Zinc	123	315	81.0	94.8	96.0	97.1	98.0	111	0	0
RSA										
Shallow Sites			**n = 67**	**n = 23**	**n = 23**	**n = 23**	**n = 23**	**n = 67**	**n = 23**	**n = 23**
Arsenic	5.9	17	0.600	3.23	2.90	3.61	7.38	10.6	8.7	0
Cadmium	0.6	3.5	<0.1	0.117	0.093	0.119	0.273	0.380	0	0
Chromium	37.3	90	14.1	47.0	48.9	52.5	58.2	77.5	87	0
Copper	35.7	197	10.2	29.9	24.4	31.8	59.5	85.3	22	0
Lead	35	91.3	2.60	6.61	6.80	7.45	7.70	10.5	0	0
Mercury	0.17	0.49	0.0050	0.0251	0.0232	0.0280	0.0416	0.0598	0	0
Zinc	123	315	29.8	70.1	69.3	80.9	105.4	115	0	0
Deep Sites			**n = 27**	**n = 9**	**n = 9**	**n = 9**	**n = 9**	**n = 27**	**n = 9**	**n = 9**
Arsenic	5.9	17	1.46	4.25	4.57	5.33	5.62	7.10	0	0
Cadmium	0.6	3.5	0.060	0.236	0.240	0.298	0.401	0.774	0	0
Chromium	37.3	90	39.0	52.9	52.1	63.4	67.4	68.0	100	0
Copper	35.7	197	16.8	29.8	22.8	31.9	54.4	73.6	11	0
Lead	35	91.3	5.62	7.59	7.21	8.70	9.80	10.5	0	0
Mercury	0.17	0.49	0.0055	0.0186	0.0103	<0.050	0.0479	0.0646	0	0
Zinc	123	315	46.7	75.9	80.5	84.7	91.1	129	0	0

Notes: (see next page)

Notes:
Units are in mg/kg unless otherwise indicated.
n = number of observations.
<' indicates that metal concentration was less than the analytical detection limit shown.
[a] *Canadian sediment quality guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (CCME 2016).*
[b] *ISQG = Interim Sediment Quality Guideline.*
[c] *PEL = Probable Effects Level.*
[d] *Minimum represents the lowest concentration in any replicate sample.*
[e] *Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles, and for comparisons against CCME guidelines.*
[f] *Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.*

5.2.4.2 Streams and Rivers

Sediment Composition

Stream and river sediments in both the LSA and RSA were mainly comprised of sand (mean range = 46% to 57%), with lesser proportions of silt (mean range = 12% to 35%), clay (mean range = 4.8% to 19%), and gravel (mean range = 0.9% to 27%; Table 5.2-7). Streams and rivers in the South Belt LSA tended to have finer sediments, on average, than streams and rivers in the North Belt LSA or RSA (Table 5.2-7).

Table 5.2-7. Summary of Stream Sediment Composition in the LSA and RSA, 2009 to 2015

LSA - North Belt	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
	n = 57	**n = 19**	**n = 19**	**n = 19**	**n = 19**	**n = 57**
Gravel >2 mm (%)	<0.1	18	13	22	50	78
Sand 2.0 mm - 0.063 mm (%)	9.0	52	48	65	78	97
Silt 0.063 mm - 4 µm (%)	<0.1	20	21	31	44	60
Clay <4 µm (%)	0.21	10	11	18	20	52
LSA - South Belt	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
	n = 21	**n = 8**	**n = 8**	**n = 8**	**n = 8**	**n = 21**
Gravel >2 mm (%)	<0.1	0.9	0.1	1.2	3.3	8.0
Sand 2.0 mm - 0.063 mm (%)	3.2	46	54	70	82	93
Silt 0.063 mm - 4 µm (%)	2.7	35	33	53	58	72
Clay <4 µm (%)	0.61	19	15	31	40	44
RSA	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
	n = 87	**n = 29**	**n = 29**	**n = 29**	**n = 29**	**n = 87**
Gravel >2 mm (%)	<0.1	27	27	39	51	81
Sand 2.0 mm - 0.063 mm (%)	5.2	57	55	67	76	99
Silt 0.063 mm - 4 µm (%)	<0.1	12	7.7	13	34	49
Clay <4 µm (%)	<0.1	4.8	1.8	5.4	21	47

Notes:
n = number of observations.
<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.

Total Organic Carbon and Nutrients

Fine sediments composed of silt and clay often contain greater concentrations of organic carbon and metals than coarse sediments. This was observed in the South Belt LSA streams and rivers, where the mean sediment TOC content was substantially greater (11%) than in the North Belt LSA (1.1%) or RSA (0.79%) sediments (Table 5.2-8), corresponding to the greater proportions of fine sediments in this study area (Table 5.2-7). Pooled data from all sites indicated that there was a strong positive correlation between TOC content and the silt fraction of sediments ($r = 0.80$, $p < 0.001$, $n = 56$), a positive correlation between TOC and clay content ($r = 0.64$, $p < 0.001$, $n = 56$), and a negative correlation between TOC and sand content ($r = -0.54$, $p < 0.001$, $n = 56$; Pearson's correlations of logit transformed percentage data). The sediment TOC content was notably high at sites AWRd (21.5%), AWRe (10.8%), S6 (33.5%), and Trout Outflow (10.6%) in the South Belt LSA (Appendix V5-3J); these sites also tended to have high silt and clay content relative to other sites.

Table 5.2-8. Summary of Stream Sediment Total Organic Carbon and Nutrient Concentrations in the LSA and RSA, 2009 to 2015

LSA - North Belt	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
	n = 57	n = 19	n = 19	n = 19	n = 19	n = 57
Total Organic Carbon (%)	<0.1	1.1	0.76	1.5	3.2	6.9
Available Ammonium (as N) (mg/kg)	<0.8	5.1	3.3	5.9	17.7	34.2
Available Nitrate (as N) (mg/kg)	<1	1.4	1.2	1.5	2.9	7.0
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1.2
Available Phosphate (as P) (mg/kg)	<2	3.1	3.3	4.2	4.6	7.7
LSA - South Belt	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
	n = 24	n = 8	n = 8	n = 8	n = 8	n = 24
Total Organic Carbon (%)	0.25	11	9.1	13	29	35
Available Ammonium (as N) (mg/kg)	2.87	20	13	20	57	74
Available Nitrate (as N) (mg/kg)	<1	all concentrations below detection limits				<30
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<6
Available Phosphate (as P) (mg/kg)	<2	3.7	3.9	4.6	6.4	8.1
RSA	**Min[a]**	**Mean[b]**	**Median[b]**	**75th percentile[b]**	**95th percentile[b]**	**Max[c]**
	n = 87	n = 29	n = 29	n = 29	n = 29	n = 87
Total Organic Carbon (%)	<0.1	0.79	0.41	1.2	2.6	6.3
Available Ammonium (as N) (mg/kg)	<0.8	3.5	3.0	3.6	8.3	20.3
Available Nitrate (as N) (mg/kg)	<1	1.4	<2	<4	2.3	3.3
Available Nitrite (as N) (mg/kg)	<0.4	all concentrations below detection limits				<1.5
Available Phosphate (as P) (mg/kg)	<1	3.1	2.8	3.6	5.3	9.3

Notes:
n = number of observations.
<' indicates that value was less than the analytical detection limit shown.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.

Concentrations of plant available nitrate and nitrite were generally near or below detection limits in streams of the LSA and RSA. Available ammonium concentrations were highest in the South Belt LSA sediments, and available phosphate concentrations were similar across study areas (Table 5.2-8).

Metals

Table 5.2-9 presents a summary of the total metal concentrations with CCME guidelines in the sediments of the LSA and RSA streams and rivers surveyed between 2009 and 2015. Overall, sediment metal concentrations tended to be lower in the streams and rivers than in the lakes of the LSA and RSA, which was likely due to the coarser material found in the stream and river beds. Sediment metals within the streams and rivers were typically greater in the LSA, particularly in the South Belt, than in the RSA, which corresponded with the patterns of finer particle size and greater TOC content found in the South Belt LSA. As observed for lakes, mean sediment metal concentrations were below CCME ISQG and PEL guidelines for cadmium, lead, mercury, and zinc at all sites. Mean sediment arsenic concentrations were greater than the ISQG of 5.9 mg/kg at one site (AWRd) in the South Belt LSA. Mean chromium concentrations were occasionally greater than the ISQG of 37.3 mg/kg in all three study areas, and the PEL for chromium of 90 mg/kg was also exceeded at Little Roberts Outflow (2011 only) within the RSA. Mean copper concentrations were greater than the ISQG of 35.7 mg/kg at one site (S6) in the South Belt LSA (Table 5.2-9).

5.3 VALUED ECOSYSTEM COMPONENTS

Valued Ecosystem Components (VECs) are those components of the biophysical environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Section 4). The selection and scoping of a VEC considers biophysical conditions and trends that may interact with the proposed Project, the variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with the Project. For an interaction to occur there must be spatial and temporal overlap between a VEC and Project component and/or activities. The selection and scoping of VECs also considers their importance to the communities potentially affected by the Project.

The scoping of freshwater sediment quality as a VEC followed the process outlined in the Assessment Methodology (Volume 2, Section 4). The scoping analysis identified freshwater sediment quality for inclusion as a VEC in the assessment. This was based on the following:

- the potential for Phase 2 activities and components to interact with local and regional freshwater sediments;
- the identification of freshwater sediment quality as important by the EIS guidelines (NIRB 2012);
- the existence of federal or territorial acts, regulations, and guidelines that directly or indirectly identify sediment quality as an important freshwater component (e.g., CCME sediment quality guidelines, MMER under the *Fisheries Act* (1985d));
- the inclusion of freshwater sediment quality as a VEC in recently completed Nunavut environmental assessments (e.g., Back River); and
- the professional recognition that Phase 2 has the potential to interact with freshwater sediments.

Table 5.3-1 summarizes the scoping considerations and rationale for including freshwater sediment quality as a VEC in this assessment.

Table 5.2-9. Summary of Stream Sediment Metals in the LSA and RSA, 2009 to 2015

	CCME Guidelines for the Protection of Aquatic Life[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th percentile[e]	95th percentile[e]	Max[f]		
LSA - North Belt										
			n = 57	**n = 19**	**n = 19**	**n = 19**	**n = 19**	**n = 57**	**n = 19**	**n = 19**
Arsenic	5.9	17	0.54	2.17	2.08	2.81	3.78	9.97	0	0
Cadmium	0.6	3.5	<0.05	0.045	<0.1	<0.1	0.051	0.079	0	0
Chromium	37.3	90	10.3	33.2	34.3	40.6	54.1	97.6	37	0
Copper	35.7	197	3.8	14.5	13.4	17.9	26.1	37.7	0	0
Lead	35	91.3	0.85	3.89	3.90	5.83	6.69	9.50	0	0
Mercury	0.17	0.49	<0.005	0.0055	0.0040	0.0062	0.0119	0.0252	0	0
Zinc	123	315	15.6	36.1	33.4	42.0	59.4	80.6	0	0
LSA - South Belt										
			n = 24	**n = 8**	**n = 8**	**n = 8**	**n = 8**	**n = 24**	**n = 8**	**n = 8**
Arsenic	5.9	17	0.06	2.99	2.03	2.79	8.59	17.8	13	0
Cadmium	0.6	3.5	<0.1	0.104	0.050	0.119	0.262	0.370	0	0
Chromium	37.3	90	7.4	22.3	19.3	21.6	39.7	52.4	13	0
Copper	35.7	197	4.3	17.1	15.0	23.9	34.4	58.4	13	0
Lead	35	91.3	<2.0	3.82	3.58	4.02	6.04	7.60	0	0
Mercury	0.17	0.49	<0.005	0.0368	0.0302	0.0432	0.0950	0.134	0	0
Zinc	123	315	13.4	43.2	40.1	55.8	74.9	87.1	0	0

	CCME Guidelines for the Protection of Aquatic Life[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th percentile[e]	95th percentile[e]	Max[f]		
RSA										
			n = 87	**n = 29**	**n = 29**	**n = 29**	**n = 29**	**n = 87**	**n = 29**	**n = 29**
Arsenic	5.9	17	0.074	1.40	1.21	1.63	2.63	7.23	0	0
Cadmium	0.6	3.5	<0.05	0.037	0.034	<0.1	0.053	0.118	0	0
Chromium	37.3	90	6.48	23.7	20.3	25.3	44.9	193	14	3.4
Copper	35.7	197	2.5	13.0	11.2	15.2	23.6	39.4	0	0
Lead	35	91.3	0.87	2.40	1.65	3.12	5.28	7.53	0	0
Mercury	0.17	0.49	<0.005	0.0050	0.0034	0.0074	0.0123	0.0199	0	0
Zinc	123	315	14.3	28.9	25.9	31.4	50.0	68.8	0	0

Notes:
Units are in mg/kg unless otherwise indicated.
n = number of observations.
<' indicates that metal concentration was less than the analytical detection limit shown.
[a] *Canadian sediment quality guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (CCME 2016).*
[b] *ISQG = Interim Sediment Quality Guideline.*
[c] *PEL = Probable Effects Level.*
[d] *Minimum represents the lowest concentration in any replicate sample.*
[e] *Replicate samples collected at the same site and date were averaged for the calculation of mean, median, and the 75th and 95th percentiles, and for comparisons against CCME guidelines.*
[f] *Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.*

Table 5.3-1. Valued Ecosystem Component(s) Included in the Assessment

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Government	
Freshwater Sediment Quality		×	×	Moderate to significant comments expressed by regulatory agencies and potentially significant regulatory considerations.

TMAC Consultation and Engagement Informing VEC or VSEC Selection

Community meetings for the Phase 2 Project were conducted in each of the five Kitikmeot communities as described in Section 3 of Volume 2. The meetings are a central component of engagement with the public and an opportunity to share information and seek public feedback. Overall, the community meetings were well attended. Public feedback (questions, comments, and concerns) about the proposed Project was obtained through open dialogue during Project presentations, through discussions that arose during the presentation of Project materials and comments provided in feedback forms. There were no direct comments received relating to freshwater sediment quality.

5.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries selected to shape this assessment were determined by the Phase 2 Project's potential effects on the freshwater environment. Spatial and temporal boundaries for the assessment of freshwater sediment quality were defined as the maximum limits within which the assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2012), and outlined in the Effects Assessment Methodology (Volume 2, Section 4).

Temporal boundaries were selected based on the different phases of Phase 2 and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect the freshwater environment.

The determination of spatial and temporal boundaries also took into account the development of the entire Hope Bay Greenstone Belt. The assessment considered both the incremental potential effects of Phase 2 as well as the total potential effects of the additional Phase 2 activities in combination with the existing and approved projects including the Doris Project and advanced exploration activities at Madrid and Boston.

5.4.1 Project Overview

Through a staged approach, the Hope Bay Project is scheduled to achieve mine operations in the Hope Bay Greenstone Belt through mining at Doris, a bulk sample followed by commercial mining at Madrid North and South, and mining of the Boston deposit. To structure the assessment, the Hope Bay Project is broadly divided into: 1) the Approved Projects (Doris and exploration), and 2) the Phase 2 Project (this application).

5.4.1.1 The Approved Projects

The Approved Projects include:

1. the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
2. the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
3. the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1217); and
4. the Madrid Advanced Exploration Project (NWB Type B Water Licence under Review).

The Doris Project

Following acquisition of the Hope Bay Project by TMAC in March of 2013, planning and permitting, advanced exploration and construction activities have focused on bringing Doris into gold production in early 2017. In 2016, the Nunavut Impact Review Board and Nunavut Water Board (NWB) granted an amendment to the Doris Project Certificate and Doris Type A Water Licence respectively, to expand mine operations to six years and mine the full Doris deposit. Mining and milling rates were increased to a nominal 1,000 tpd to 2,000 tpd.

The Doris Project includes the following:

- the Roberts Bay offloading facility: marine jetty, barge landing area, beach and pad laydown areas, fuel tank farm/transfer station, and quarries;
- the Doris Site: 280-person camp, laydown area, service complex (e.g., workshop, wash bay), quarries, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerators, explosives storage, and diesel power plant;
- Doris Mine works and processing: underground portal, temporary waste rock pile, ore stockpile, and processing plant;
- water use for domestic, drilling and industrial uses, and groundwater inflows to underground development;
- Tailings Impoundment Area (TIA): Schedule 2 designation of Tail Lake with two dams (North and South dams), roads, pump house, and quarry;
- all-weather roads and airstrip, winter airstrip, and helicopter pads; and
- water discharge from the TIA will be directed to the outfall in Roberts Bay.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been ongoing since the 1990s. Much of the previous work for the program was based out of the Windy Lake (closed in 2008) and Boston sites (put into care and maintenance in 2011). All exploration activities are currently based from the Doris Site with plans for some future exploration at the Boston Site. Components and activities for the Hope Bay Regional Exploration Project include:

- staging of drilling activities out of Doris or Boston sites; and
- operation of exploration drills in the Hope Bay Belt area, which are supported by helicopter.

Boston Advanced Exploration

The Boston Advanced Exploration Project, which operates under a Type B Water Licence, includes:

- the Boston exploration camp, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, and a heli-pad;
- mine works consisting of underground development for exploration drilling and bulk sampling, temporary waste rock pile, and ore stockpile;
- potable water and industrial water taken from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

Since the construction of Boston will require the reconfiguration of the entire site, construction and operation of all aspects of the Boston Site will be considered as part of the Phase 2 Project for the purposes of the assessment.

Madrid Advanced Exploration

In 2014, TMAC applied for an advanced exploration permit to conduct a bulk sample at the Madrid North and Madrid South sites, which are approximately 4 km south of the Doris Site. The program includes extraction of a 50,000 tonne bulk sample, which will be trucked to the mill at the Doris Site for processing and placement of tailings in the TIA. All personnel will be housed at the Doris Site.

The Water Licence application is currently before the NWB. Madrid advanced exploration includes constructing and operating of the following at each of the sites:

- Madrid North and Madrid South: workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station, contact water pond, and quarry;
- Madrid North and Madrid South mine works: underground portal and works, waste rock pad, ore stockpile, compressor building, brine mixing facility, saline storage tank, air heating facility, and vent raises; and
- a road from the Doris Site to Madrid with branches to Madrid North, Madrid North vent raise, and the Madrid South portal.

5.4.1.2 The Phase 2 Project

The Phase 2 Project includes the construction and operation of commercial mining at the Madrid (North and South) and Boston sites, the continued operation of Roberts Bay and the Doris Site to support mining at Madrid and Boston, and the Reclamation and Closure and Post-Closure phases of all sites. Excluded from the Phase 2 Project, for the purposes of the assessment, are the reclamation and closure and post-closure of unaltered components of the Doris Project as currently permitted and approved.

Construction

Phase 2 construction will use the infrastructure associated with Approved Projects.

Additional infrastructure to be constructed for the proposed Phase 2 Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, and development of a west road to facilitate access);
- construction of an off-loading cargo dock at Roberts Bay (including a fuel pipeline, expansion of the fuel tank farm and laydown area);
- construction of infrastructure at Madrid North and Madrid South to accommodate mining;
- complete development of the Madrid North and Madrid South mine workings;
- construction of a process plant, fuel storage, power plant, and laydown at Madrid North;
- all weather access road (AWR) and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston with associated quarries;
- all infrastructure necessary to support mining activities at Boston including construction of a new 200-person camp at Boston and associated support facilities, additional fuel storage, laydown area, ore pad, waste rock pad, process plant, airstrip, diesel power plant, and dry-stack tailings management area (TMA) at Boston; and
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston.

Operation

Phase 2 Project represents the staged development of the Hope Bay Belt beyond the Doris Project (Phase 1). Phase 2 operations includes:

- mining of the Madrid North, Madrid South, and Boston deposits;
- transportation of ore from Madrid North, Madrid South and Boston to Doris for processing, and transportation of concentrate from process plants at Madrid North and Boston to Doris for final gold refining once the process plants at Madrid North and Boston are constructed;
- use of Roberts Bay and Doris facilities, including processing at Doris and maintaining and operating the Robert's Bay outfall for discharge of water from the TIA;
- operation of a process plant at Madrid North to concentrate ore, and disposal of tailings at the Doris TIA;
- operation of a process plant at Boston to concentrate ore, and disposal of tailings to the Boston TMA; and
- ongoing use and maintenance of transportation infrastructure (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Section 5.5):

- Camps and associated infrastructure, laydown areas and quarries, buildings and physical structures will be decommissioned. All foundations will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Using non-hazardous landfill, facilities will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered rock. Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston All-Weather Road and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts, or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.
- A low-permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached. The balance of the berms will be left in place to prevent localised permafrost degradation.

5.4.2 Spatial Boundaries

Spatial boundaries are determined based on the anticipated magnitude and spatial extent of Project effects. Spatial boundaries are determined by the location and distribution of VECs and are here defined as the anticipated zone of influence between Project component/activities and freshwater sediment quality.

There are three zones of influence related to freshwater sediment quality: the Project Development Area (PDA), the Local Study Area (LSA), and the Regional Study Area (RSA).

5.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 5.4-1 and is defined as the area which has the potential for infrastructure to be developed as part of the Phase 2 Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for refinement in the final placement of a structure through detailed design and necessary in-field modifications during construction phase. Areas with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Phase 2 Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Section 2 (Project Description).

5.4.2.2 Local Study Area

The LSA for the assessment of freshwater sediment quality is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on the freshwater environment due to an interaction with a Project component(s) or physical activity. The LSA includes the watersheds for key waterbodies, such as the Aimaokatalok Lake and Doris Lake, and is the same used for the surface hydrology, water quality, and fish and fish habitat VECs (Figure 5.2-2).

5.4.2.3 Regional Study Area

The RSA for the assessment of freshwater sediment quality is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur. The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA for the freshwater sediment quality VEC includes portions of the Angimajuq watershed and the Koignuk River watershed located to the west of the PDA, and is the same used for the surface hydrology, water quality, and fish and fish habitat VECs (Figure 5.2-2).

5.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, Phase 2 is a continuation of development currently underway. Phase 2 has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston and three mine sites: Madrid North, Madrid South and Boston. Development, operation and closure of the Phase 2 Project will overlap mining and post-mining activities at the existing Doris mine. As such, the temporal boundaries of this Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities during Phase 2.

For the purposes of the EIS, distinct phases of the Project are defined (Table 5.4-1). It is understood that construction, operation, and reclamation and closure activities will, in fact, overlap among sites; this is outlined in Table 5.4-1 and further described in Volume 3, Section 2 (Project Description).

Table 5.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Sediment Quality

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 to 5	2019 to 2023	5	• **Doris**: expansion of the Doris TIA and accommodations (Year 1); • **Madrid North:** construction of process plant and road to Doris TIA (Year 1); • **All-weather Road**: construction (Year 1 to 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 to 5).
Operation	1 to 14	2019 to 2032	14	• **Doris**: milling and infrastructure use (Year 1 to 14); • **Madrid North:** mining, ore transport to Doris mill, ore processing and concentrate transport to Doris mill (Year 2 to 13); • **Madrid South:** mining, ore transport to Doris mill (Year 11 to 14); • **All-weather Road**: operational (Year 4 to 16); • **Boston**: winter access road operating (Year 1 to 3); mining (Year 4 to 14); ore transport to Doris mill (Year 4 to 5); processing ore (Year 6 to 14); and concentrate transport to Doris mill (Year 6 to 13).
Reclamation and Closure	14 to 17	2032 to 2035	4	• **Doris**: Accommodations and facilities will be operational during closure; mining, milling, and TIA decommissioning (Year 15 to 17); • **Madrid North:** all components decommissioned (Year 14 to 15); • **Madrid South:** all components decommissioned (Year 15 to 16); • **All-weather Road**: road will be operational (Year 15 to 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 to Year 16).
Post-Closure	16 to 19	2034 to 2037	4	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

The assessment also considers a Temporary Closure phase should there be a suspension of the Phase 2 Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, Phase 2 would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (one to two year duration would be typical).

5.5 PROJECT-RELATED EFFECTS ASSESSMENT

5.5.1 Methodology Overview

To provide a comprehensive understanding of the potential effects for the Project, the Phase 2 components and activities are assessed on their own as well as in the context of the Approved Projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Phase 2 Project and the VECs or VSECs;
2. Identify the resulting potential effects of those interactions;
3. Identify mitigation or management measures to eliminate or reduce the potential effects;
4. Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for Phase 2 in isolation;
5. Identify residual effects of Phase 2 in combination with the residual effects of Approved Projects; and
6. Determine the significance of combined residual effects.

After the identification of potential interactions between the Phase 2 Project and freshwater sediment quality (Step 1, Section 5.5.2), the potential effects of these interactions were identified (Step 2, Section 5.5.2). Mitigation and management measures were then considered (Step 3, Section 5.5.3). If the application of these measures were expected to effectively mitigate the effects from the Phase 2 Project, the Phase 2-related effects to freshwater sediment quality were characterized as negligible and not identified as residual effects (Step 4, Section 5.5.4). In parallel, the mitigation of potential effects of Phase 2 in combination with the Approved Projects were considered, and if mitigations measures were expected to effectively mitigate the effects from the Phase 2 and Approved projects, the potential effects were considered negligible and not further characterized (Step 5, Section 5.5.4).

All remaining potential effects were then considered residual effects, and further characterized (Step 6, Section 5.5.5.2) using the following attributes:

- direction (positive, neutral, or negative);
- magnitude (negligible, low, moderate, or high);
- duration (short, medium, long);
- frequency (infrequent, intermittent, continuous);
- geographic (spatial) extent (PDA, LSA, RSA, beyond regional); and
- reversibility (reversible, reversible with effort, irreversible).

The rating criteria for the assessment of residual effects are described in the Effects Assessment Methodology section (Volume 2, Section 4) and are further defined for freshwater sediment quality in Table 5.5-6. The CCME sediment quality guidelines for the protection of aquatic life (CCME 2016) were used, when available, as assessment thresholds for the determination of magnitude. The significance of each residual effect (Step 6, Section 5.5.5.2) was determined by considering the characterization of each residual effect with an assessment of the probability of effects and the confidence in the baseline data and predictions of the effects of the Phase 2 Project and the Hope Bay Development on the freshwater environment.

5.5.1.1 Sediment Quality Indicators

Sediment quality is an aggregate definition that encompasses a complex suite of parameters and indicators that describe the aquatic environment and its ability to sustain ecological and biogeochemical functions. The assessment of the potential effects of the Phase 2 Project on freshwater sediment quality was based on indicators that described the most probable and significant interactions between the Phase 2 Project and the freshwater environment (Table 5.5-1). These indicators were chosen because they have the following characteristics:

- specific empirical definitions;
- established analytical measurement methodologies;
- existing baseline information;
- quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life; and
- responsive to the potential effects of industrial and mining activities in the Arctic.

Table 5.5-1. Freshwater Sediment Quality Indicators for the Assessment of Effects

Indicator	Description	Interaction with Project
Particle Size	The relative proportion of silt-, clay-, sand-, and gravel-sized particles	Project activities may disturb sediments, increase runoff of deposited sediment, or discharge suspended material
Nutrients and Organic Carbon	Nutrients adsorbed to sediment particles or dissolved in sediment interstitial water and organic material in sediments	Project activities may contribute organic material to waterbodies directly through discharge, runoff, or deposition, or indirectly through nutrient addition (eutrophication)
Metals	Metals adsorbed to sediment particles or dissolved in sediment interstitial water	Contribute metals (dissolved or particulate) through runoff, discharge, and deposition
Hydrocarbons	Petroleum hydrocarbon compounds	Contribute petroleum hydrocarbons through runoff, discharge, and deposition

For the effects assessment, thresholds are applied to the sediment quality indicators described in Table 5.5-2. These thresholds are based on CCME sediment quality guidelines for the protection of aquatic life, when applicable. In some cases, baseline concentrations of sediment metals (e.g., arsenic, chromium, and copper) were naturally higher than CCME guidelines (see Section 5.2.4.1 and 5.2.4.2); for these naturally enriched metals, baseline concentrations were also considered in the determination of acceptable threshold concentrations. If sediment quality guidelines were not available, the thresholds may be defined based on existing conditions defined by the baseline sampling program.

Table 5.5-2. Assessment Thresholds for Freshwater Sediment Quality Indicators

		CCME Guideline Concentration (mg/kg)	
Indicator	**Parameter**	**ISQG†**	**PEL†**
Particle size	Particle size	*No regulatory threshold value; threshold set to 75th percentile of baseline values*	
Nutrients and Organic Carbon	Nutrients and TOC	*No regulatory threshold value; threshold set to 75th percentile of baseline values*	
Metals	Arsenic*	5.9	17
	Cadmium	0.6	3.5
	Chromium*	37.3	90
	Copper*	35.7	197
	Lead	35.0	91.3
	Mercury	0.170	0.486
	Zinc	123	315

Indicator	Parameter	CCME Guideline Concentration (mg/kg)	
		ISQG†	PEL†
Hydrocarbons	Petroleum hydrocarbons	*Range of guidelines for petroleum hydrocarbon compounds (CCME 2016)*	

† CCME freshwater sediment ISQG and PEL for the protection of aquatic life (CCME 2016).
** Baseline concentrations of these metals were naturally higher than CCME ISQGs in several freshwater sediment samples, particularly from lake sediments (Tables 5.2-6 and 5.2-9). When the 75th percentile of baseline concentrations of a metal is higher than the ISQG for that metal, the threshold is set at the 75th percentile of baseline concentrations.*

5.5.2 Identification of Potential Effects

The Phase 2 Project has the potential to interact with the freshwater environment through a number of activities, pathways, and mechanisms. Project activities have been grouped into broad components as described in Section 4.3.4.1 of the Effects Assessment Methodology (Volume 2, Section 4). The interactions between the Phase 2 Project and freshwater sediment quality were further refined by an *interaction group*. Interaction groups are interaction pathways that share similar modes of interaction with the Project, specific mitigation and management measures, assessment thresholds, and key indicators. For example, 'fuel storage and handling' and 'TMA roads use and maintenance' in the Boston area during the Operation phase were both assigned to the *Fuels, Oils, and Polycyclic Aromatic Hydrocarbons* (PAH) interaction group because both project components may interact with freshwater sediment quality through activities related to the storage and use of fuel. The defined interaction groups for the assessment of effects to freshwater sediment quality are the following:

- *Site Preparation, Construction, and Decommissioning*—activities that include the clearing of overburden, earthworks, and construction activities for pads and infrastructure.
- *Site and Mine Contact Water*—water that contacts infrastructure, mine surfaces and operations, including runoff from waste rock storage areas and ore storage areas, water management, drilling water, and underground mine water. The site and mine contact water interaction group includes the operation of the contact water treatment plant at the Boston site.
- *Quarries and Borrow Pits* - activities related to the operation of quarries and borrow pits.
- *Explosives* - Project activities related to the transport, manufacture, storage, and use of explosives.
- *Fuels, Oils, and PAH*—activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.
- *Treated Sewage Discharge* –treated discharge from domestic water treatment facilities.
- *Dust Deposition*—activities that generate dust, including vehicle traffic, airstrip activity, and quarry and borrow pit activities that can then be deposited in freshwater receiving environment.

The potential interactions between the Project and the freshwater environment are presented in Table 5.5-3. These components were judged to have probable or likely interactions with the freshwater environment. These potential interactions may be direct or indirect, and this screening step did not consider application of mitigation and management measures.

Table 5.5-3. Project Interaction with the Freshwater Sediment Quality VEC

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
Roberts Bay	**Construction – proposed Phase 2 infrastructure**							
	Dock access road	×						×
	Fuel pipeline and tank farm	×				×		
	Construction and Operation – use of existing approved and permitted infrastructure							
	Fuel tank farm					×		
	Laydown areas		×		×	×		×
	Roberts Bay-Doris road use and maintenance					×		×
	Site roads use and maintenance					×		×
	Water Management System		×					
	Operation – proposed Phase 2 infrastructure							
	Use of dock access road					×		×
	Fuel pipeline and tank farm					×		
	Quarry			×				×
	Reclamation and Closure – proposed Phase 2 infrastructure							
	Site surface infrastructure	×				×		×
	Dock access road	×				×		×
	Quarry			×				×
	Temporary Closure							
	Care and maintenance		×			×		
Doris	**Construction – proposed Phase 2 infrastructure**							
	Expansion of Project Development Area	×						
	Expansion of accommodations (280 person capacity, expanded to 400 person capacity)	×					×	
	Quarry			×				×
	Raising the TIA South Dam	×						
	TIA perimeter road extensions	×						
	TIA West Dam	×						
	Road to TIA South Dam	×						×
	Operation – use of existing approved and permitted infrastructure							
	Airstrip, winter ice strip and helicopter pad					×		×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Site facilities (sewage treatment facilities, domestic water treatment, fire suppression)						×	
	Chemical and hazardous material management facilities					×		
	Fuel storage and handling					×		
	Incinerator					×		
	Ore stockpile		×					×
	Site roads use and maintenance					×		×
	Storage and handling of explosives				×	×		
	Surface infrastructure (maintenance facilities, warehouses, laydown areas, waste management facilities)		×			×		×
	Water discharge to the receiving environment		×					
	Water management system		×					
	Operation – proposed Phase 2 infrastructure							
	Accommodations (expanded)		×				×	
	Quarry			×				×
	TIA road use and maintenance		×					×
	TIA storage		×					
	Reclamation and Closure – proposed Phase 2 infrastructure							
	Accommodations (expanded)	×					×	×
	Quarry	×		×				×
	TIA roads (perimeter and South Dam)	×				×		×
	TIA	×	×					
	Temporary Closure							
	Care and maintenance		×			×		
Madrid North	**Construction – use of existing approved and permitted infrastructure**							
	Fuel storage and handling					×		
	Ore stockpile		×					×
	Quarry			×				×
	Site roads							×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)							×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×			×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Waste rock pile		×					×
	Water management system		×					
	Construction – proposed Phase 2 infrastructure							
	Expansion of site pad (waste rock stockpile)	×	×					×
	Process plant (concentrator)	×						
	Power plant	×						
	Water discharge to the receiving environment							
	Water management system (including expanded CWP)	×	×					
	Operation – use of existing approved and permitted infrastructure							
	Doris - Madrid road use and maintenance		×			×		×
	Fuel storage and handling					×		
	Madrid North access road use and maintenance		×			×		×
	Ore stockpile		×					×
	Quarry			×				×
	Site roads use and maintenance					×		×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)		×			×		×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×			×
	Waste rock pile		×					×
	Water management system		×					
	Operation – proposed Phase 2 infrastructure							
	Water discharge to the receiving environment		×					
	Water management system (including CWP)		×					
	Reclamation and Closure – proposed Phase 2 infrastructure							
	Inter-site roads	×				×		×
	Site surface and mining infrastructure	×	×			×		×
Madrid South	**Construction – use of existing approved and permitted infrastructure**							
	Fuel storage and handling					×		
	Ore stockpile		×					×
	Quarry			×				×
	Site roads							×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)							×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×			×
	Waste rock pile		×					×
	Water management system		×					
	Construction - proposed Phase 2 infrastructure							
	Expansion of Project Development Area	×						
	Expansion of site pad (waste rock stockpile)	×	×					×
	Water discharge to the receiving environment		×					
	Water management system (including expanded CWP)	×	×					
	Operation - use of existing approved and permitted infrastructure							
	Doris - Madrid road use and maintenance					×		×
	Fuel storage and handling					×		
	Ore stockpile		×					×
	Quarry			×				×
	Site roads use and maintenance					×		×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)					×		×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×			×
	Waste rock pile		×					×
	Water management system – Type B licence		×					
	Operation - proposed Phase 2 infrastructure							
	Water discharge to the receiving environment		×					
	Water management system (including CWP)		×					
	Reclamation and Closure - proposed Phase 2 infrastructure							
	Inter-site roads	×				×		×
	Site surface and mining infrastructure	×				×		×
Madrid-Boston All-Weather Road	**Construction - use of existing approved and permitted infrastructure**							
	Madrid-Boston winter road					×		×
	Construction - proposed Phase 2 infrastructure							
	All weather road (grading, backfill, excavation, drainage)	×						×
	Construction accommodations	×					×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Quarries	×		×				×
	Water crossings	×						×
	Operation – use of existing approved and permitted infrastructure							
	Madrid-Boston winter road					×		×
	Operation – proposed Phase 2 infrastructure							
	All weather road use and maintenance					×		×
	Quarries			×				×
	Water crossings		×					
	Reclamation and Closure – proposed Phase 2 infrastructure							
	All-weather road, quarries and associated infrastructure	×						×
Boston	**Construction – proposed Phase 2 infrastructure**							
	Accommodations (sewage treatment facilities, domestic water treatment, fire suppression)	×					×	×
	Fuel storage and handling	×				×		
	Incinerator	×						
	Landfarm	×						×
	Ore stockpile	×	×					×
	Overburden pile	×						×
	Quarry			×				×
	Second mine portal	×						×
	Site roads	×						×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility)	×						×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×			×
	Waste rock pad and pile	×	×					×
	Water discharge to the environment		×					
	Water management system	×	×					
	Process plant (concentrator)	×						
	Dry-stack TMA	×	×					×
	TMA roads	×						×
	TMA water management system	×	×					

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Operation – proposed Phase 2 infrastructure							
	Accommodations (sewage treatment facilities, domestic water treatment, fire suppression)						×	×
	Fuel storage and handling					×		
	Incinerator					×		×
	Landfarm							×
	Ore stockpile		×					×
	Overburden pile		×					×
	Quarry			×				×
	Site roads and maintenance					×		×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility)		×			×		×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×			×
	Waste rock pile		×					×
	Water discharge to the environment		×					
	Water management system		×					
	Process plant (concentrator)		×					
	Dry-stack TMA		×					×
	TMA roads use and maintenance					×		×
	TMA water management system		×					
	Reclamation and Closure – proposed Phase 2 infrastructure							
	Site surface and mining infrastructure	×	×			×	×	×
	TMA and associated infrastructure	×	×					×
Boston Airstrip	**Construction – proposed Phase 2 infrastructure**							
	Access road	×						×
	Airstrip and lighting	×						×
	Project Development Area	×						×
	Quarry			×				×
	Operation – proposed Phase 2 infrastructure							
	Access road use and maintenance					×		×
	Airstrip and lighting					×		×
	Quarry			×				×
	Reclamation and Closure – proposed Phase 2 infrastructure							
	Site surface infrastructure	×						×

Activities and infrastructure interact with the environment through discrete pathways. These pathways describe specific mechanisms of interactions that are useful for specifying the physical relationship between the Phase 2 Project component and the freshwater environment, for identifying applicable mitigation measures, and for characterizing the residual effects. For the freshwater sediment quality effects assessment, the following pathways were defined:

- *runoff*, which describes the transport of material or compounds from the terrestrial environment into the freshwater environment by precipitation or snowmelt;
- *discharge*, which is the directed input of water into the freshwater environment;
- *seepage*, which describes the flow of water through the active layer and taliks;
- *physical*, which is the direct physical effects of Project activities in the freshwater environment; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the freshwater environment.

The pathways applicable to each Project interaction group are summarized in Table 5.5-4. These pathways were then used through the effects assessment to describe the potential effects, identify mitigation and management measures, and characterize the residual effects from Project activities.

The potential effects of each of the Project activities identified in Table 5.5-4 are characterized below in the Sections 5.5.2.1 to 5.5.2.7. The potential effects analysis considered the proposed Project activities (Volume 2) and the pathway(s) linking the Project activities to the freshwater environment. The potential effects are identified prior to the application of mitigation or management measures. The subsequent characterization of the potential effects considers mitigation and management measures, and may show that the potential effects are negligible.

Table 5.5-4. Pathways of Interactions with the Freshwater Environment for the Freshwater Sediment Quality Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Site preparation, construction, and decommissioning activities	Runoff, physical	Particle size, TOC, nutrients, metals, hydrocarbons	Construction, and Reclamation and Closure
Site and mine contact water	Runoff, discharge, seepage	Particle size, TOC, nutrients, metals, hydrocarbons	Construction, Operation, Reclamation and Closure, Post-closure, Temporary Closure
Quarries	Runoff, aerial deposition	Particle size, TOC, nutrients, metals	Construction, Operation, Reclamation and Closure
Explosives	Runoff, aerial deposition	TOC, nutrients, hydrocarbons	Construction and Operation
Fuels, oils, PAH	Runoff, aerial deposition	TOC, nutrients, hydrocarbons	Construction, Operation, Reclamation and Closure, Post-closure, Temporary Closure
Treated Sewage Discharge	Discharge	TOC, nutrients, hydrocarbons	Construction, Operation, and Reclamation and Closure
Dust deposition	Aerial deposition	Particle size, nutrients, metals, hydrocarbons	Construction, Operation, and Reclamation and Closure

5.5.2.1 Potential Effects from Site Preparation, Construction and Decommissioning Activities

During the Construction phase, ground preparation will be required throughout the PDA to construct necessary Phase 2 infrastructure, including buildings, roads, and mine works. As outlined in Table 5.5-3, the Phase 2 Project also includes the expansion of the TIA, which will require additional construction activities that were not authorized by the 2AM-DOH1323 Water Licence. Site preparation and construction activities will involve vegetation clearing, the removal and relocation of surficial materials, and the construction of pad areas from surficial material, borrow material, and quarried rock. The activities would also include the construction of water management structures, such as ditches, diversion structures, and berms to mitigate runoff, and earthworks for the TIA (Doris area) and the TMA (Boston area). The decommissioning and reclamation of Phase 2 infrastructure will similarly require surface contact and the transportation and relocation of surficial materials.

Landscape disturbance (ground works) has the potential for effects on freshwater sediment quality. The primary pathway for these potential effects would be runoff (i.e., the transport of material in overland flow). This would occur primarily during snowmelt and freshet in the spring, during precipitation events in the summer and fall, and would be absent in the winter. Runoff from areas undergoing site preparation or decommissioning could affect freshwater sediment quality by changing sediment particle size composition (sedimentation of eroded material) and by contributing metals, nutrients, organic matter, and hydrocarbons (from the use of fuels and oils) into the freshwater environment.

In-water or near-water activities including the installation or decommissioning of stream-crossing infrastructure for the AWRs and the installation of the discharge pipeline in Aimaokatalok Lake have the potential to disturb and rework sediments. Four AWRs are proposed that will cross streams including the Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, , the Madrid South AWR, and the Madrid-Boston AWR. Culverts or bridges will be installed in or over streams that will be crossed by roads to allow for the flow of water and passage of fish.

The potential effects from site preparation, construction, and decommissioning activities may occur during the Construction and Reclamation and Closure phases.

Effects that may occur via dust deposition are considered separately (Section 5.5.2.7).

5.5.2.2 Potential Effects from Site and Mine Contact Water

Site contact water is defined as the runoff from snowmelt and precipitation events that interacts with constructed site surfaces including roads and laydown areas. A comprehensive geochemical characterization program was conducted to assess the metal leaching and acid rock drainage (ML/ARD) potential (See Section 5, Geochemistry); only rock from quarries defined as suitable for use on the basis of a low risk of ARD and low risk of metal leaching under neutral pH conditions, will be used as construction material. Flowing surface water in runoff can contact these surfaces, and subsequently transport suspended material, metals, nutrients, organic matter, and petroleum hydrocarbon compounds into the freshwater environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Phase 2 Project.

The use of the Doris-Boston WRR is considered as part of the *Site and Mine Contact Water* interaction group. The WRR will be used during the Construction phase prior to the completion of the AWR. Use of the WRR is authorized by the existing Type “B” water licence for the Boston Exploration Site. The construction of winter ice roads may affect vegetation cover along the shores of waterbodies, which could increase runoff and erosion. This could introduce suspended sediments, metals, and nutrients into freshwater environments.

Mine contact water is defined as the underground water removed from mine works; water that interacts with waste rock storage areas, ore stockpiles, and water management structures (e.g., CWPs); mill process water; and water in the TIA. Operation of the water treatment plant at the Boston site is included in the *site and mine contact water* interaction group. The contact water discharge via the Roberts Bay Discharge System at the Doris site is not included in the freshwater sediment quality assessment because the effluent is directed to the marine environment (see Volume 5, Section 9).

The pathways of interaction between mine contact water and the freshwater environment are runoff, discharge, and seepage. Potential effects from mine contact water may occur during all Project phases. Mine contact water, including water interacting with overburden, waste rock, and tailings, could affect the freshwater water quality by changing pH (interaction with geological material), and contributing TSS (erosion), metals, nutrients (contact with blasting residues), and other water quality indicators such as chloride (e.g., saline groundwater) into the freshwater environment. A change in freshwater water quality could secondarily affect sediment quality through water-sediment exchange processes or through the settling of particulate material onto the lake, stream, or river bed. Depending on the environmental conditions and the biogeochemical properties of the parameter in question, sediments can act as a net sink for introduced metals, nutrients, organic matter, or contaminants or as a net source if conditions favour the release of these elements or compounds from sediments into the water.

5.5.2.3 Potential Effects from Quarries and Borrow Pits

Quarries and borrow sources will be developed to meet the requirements for construction and maintenance. The pathway of interaction between quarries and the freshwater environment is through runoff, and this may occur during the Construction, Operation, and Reclamation and Closure phases. Contact water in quarries and borrow pits may transport metals, nutrients (from contact with blasting residues - covered in the *Explosives* interaction pathway) and suspended sediments into the freshwater environment. Runoff from quarries and borrow pits could change the particle-size composition of sediments (because of the deposition of eroded sediments) and add metals, nutrients, organic material, and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment, where they have the potential to interact with sediments.

Effects that may occur via dust deposition are considered separately (Section 5.5.2.7).

5.5.2.4 Potential Effects from Explosives

Ammonium nitrate-fuel oil (ANFO) explosives will be used as the explosive for quarries and mine development and production. Components of the explosives have the potential for effects on freshwater sediment quality because of the presence of ammonium nitrate and petroleum hydrocarbons. The pathways of interaction between explosives and the freshwater environment are runoff and aerial deposition, and the potential effects may occur during Construction and Operations phases. Runoff and deposition of explosives (or blasting residues) into the freshwater environment can affect sediment quality directly by increasing the concentrations of ammonia and nitrate, and indirectly as a nutrient source for primary producers that could affect sediment TOC and dissolved oxygen concentrations. The petroleum hydrocarbon component, either as dissolved constituents or particle-attached compounds, is a minor fraction of the explosives by weight. The petroleum hydrocarbons components of the explosives are not considered further as a potential effect to sediment quality because of their small relative proportion in the ANFO explosives, the expectation that is small fraction will be combusted, and the proposed mitigation and management measures.

The potential effects from explosives may occur during the Construction and Operation phases.

5.5.2.5 Potential Effects from Fuels, Oils, and PAH

The *Fuels, Oils, and PAH* interaction group includes the storage and transport of fuels and petroleum hydrocarbons, fueling and maintenance operations, and the incineration of waste that may create PAH by incomplete combustion. The primary pathways of interactions between these sources of hydrocarbons and the freshwater environment are runoff and aerial deposition. Activities at facilities, laydown areas, fuel storage areas, and waste management areas can deposit hydrocarbon compounds such as oil or grease onto surfaces that can subsequently be transported into freshwater environments in runoff. Combustible waste, including the solids from sewage treatment, will be combusted using an incinerator. Incomplete combustion can create airborne hydrocarbons that can be deposited into freshwater environment via deposition or runoff. The potential effects from fuels and other hydrocarbons may occur during the Construction, Operation, Reclamation and Closure, and Temporary Closure phases.

The potential effects from spills, including fuel spills, are not assessed as part of the normal operating conditions, and are considered in the Accidents and Malfunctions section of the EIS (Volume 7, Section 1).

5.5.2.6 Potential Effects from Treated Sewage Discharge

Treated sewage from domestic water treatment facilities at Boston will be discharged to Aimaokatalok Lake during the Construction, Operations, and Reclamation and Closure phases. Discharge of treated sewage effluent may affect the freshwater environment by increasing nutrient concentrations and by altering oxygen dynamics by the introduction of organic material. These changes can affect sediment quality by increasing nutrient and TOC concentrations in sediments, and by altering the redox chemistry of sediments and overlying waters, which could affect water-sediment exchange of metals and nutrients. The potential effects from treated sewage discharge may occur during the Construction, Operations, and Reclamation and Closure phases.

Domestic sewage from Madrid North, Madrid South, and Doris will be treated and discharged to the TIA. This TIA water will subsequently be discharged to the marine environment and is not expected to interact with the freshwater environment.

5.5.2.7 Potential Effects of Dust Deposition

Dust can be generated by a variety of Project activities, including vehicle traffic, blasting activities, quarry operations, and rock processing. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of the Project-generated dust is the primary pathway of interaction. Dust deposition into the freshwater environment may affect freshwater sediment quality by introducing deposited material onto lake, stream, and river beds, which could change the particle-size composition of sediments, and increase the concentrations of metals, nutrients, or organic material in sediments. The potential effects from dust deposition may occur during all phases of the Project.

5.5.3 Mitigation and Adaptive Management

5.5.3.1 Mitigation by Project Design

The following measures were included in the design of the project to minimize or eliminate potential effects on the freshwater environment:

- Utilization of existing infrastructure associated with the Doris Project.
- Inclusion of climate change projections for key climatic and hydrologic design details.

- Construction of roads and pipelines as far as is practical from stream channel crossings and wet, boggy areas where fish habitat may be disturbed.
- Planned set-backs and buffer zones from aquatic and riparian environments.
- Avoidance, as feasible, of sensitive features, including riparian ecosystems and floodplains, esker complexes, wetlands, shallow open ponds, marshes, and bedrock cliffs.
- Only geochemically suitable rock quarries and borrow sources will be used to construct roads, pads, and structures.
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer, and ultimately to the freshwater environment.
- Fuel storage tanks will be within lined facilities to provide secondary containment, should leaks occur.
- Erosion potential will be reduced by working during periods of low runoff (e.g., winter) as much as possible.
- Water will be recycled / reused where possible.

The design of the Phase 2 Project also included adherence to regulatory requirements relevant to the mitigation of potential effects on the freshwater environment. These regulatory requirements included the following:

- The operation of incinerators will comply with Nunavut standards (Nunavut Department of Environment 2012), *Canada-Wide Standards for Dioxins and Furans* (CCME 2001a) and *Canada-Wide Standards for Mercury Emissions* (CCME 2000).
- Treated effluent from Boston activities will be discharged to Aimaokatalok Lake in compliance with the Type A Water Licence and Metal Mining Effluent Regulation (MMER; 2002a) requirements in a manner that will facilitate mixing and dispersion and consequently result in dilution to concentrations protective of aquatic life within 250 m of the discharge point.
- Blasting restrictions outlined in DFO's *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky 1998) will be implemented for blasting occurring near water.
- Culvert maintenance will be conducted following the guidance provided in *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016), which adheres to the *Fisheries Act* (1985d).
- In-water work will be conducted during approved timing windows presented in *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat* (DFO 2013).

5.5.3.2 Best Management Practices

Reducing potential effects to freshwater sediment by avoidance is the most effective mitigation measure to reduce the potential for serious damage or harm. The design of the Project included a number of features to avoid potential effects. Further management and mitigation measures are described in relevant management plans provided as annexes to Volume 8, including the following:

- Doris Project Domestic Wastewater Treatment Management Plan (Annex 5);
- Hope Bay Project Groundwater Management Plan (Annex 6);

- Water Management Plan: Madrid Advanced Exploration Program, North and South Bulk Samples (Annex 7);
- Water Management Plan, Hope Bay Project (Annex 8);
- Water and Ore/Waste Rock Management Plan (Annex 9);
- Sewage Treatment Plan Operation and Maintenance Plan (Annex 10);
- Hope Bay Project Doris Tailings Impoundment Area Operations, Maintenance, and Surveillance Manual (Annex 11);
- Waste Rock and Ore Management Plan (Annex 12);
- Hope Bay Project Interim Non-hazardous Waste Management Plan (Annex 13);
- Doris North Landfarm Management and Monitoring Plan (Annex 14);
- Hope Bay Project Hazardous Waste Management Plan (Annex 15);
- Incinerator Management Plan (Annex 16);
- Hope Bay Project Quarry Management and Monitoring Plan (Annex 17);
- Quarry Blasting Operations Management Plan (Annex 18);
- Air Quality Management Plan (Annex 19);
- Hope Bay Project Phase 2 Aquatic Effects Monitoring Plan (Annex 21); and
- Hope Bay Project, Phase 2 Conceptual Closure and Reclamation Plan (Annex 27).

Specific mitigation and management measures relevant to the assessment of effects on freshwater sediment quality include the following:

- Implementation of sediment control measures for works in or near waterbodies and watercourses, such as use of silt fences or coconut matting at drainage points and the minimization of vegetation clearing.
- Implementation of erosion control measures where necessary, such as capping of soils exposed during construction activities with rock.
- Regular inspections will be conducted to ensure erosion and sediment control measures are functioning properly; necessary repairs and adjustments will be conducted in a timely manner. Efforts shall be made to minimize the duration of any in-water works and minimize disturbance of riparian vegetation.
- Quarries will be developed to the extent possible to ensure that water entering the quarry from precipitation and snowmelt is retained within the quarry boundary. If required, a quarry sump will be used to collect water. The sump water will be sampled and discharged to the environment only if discharge requirements are met. Non-compliant water that needs to be discharged will be transported to CWPs for management and/or transported directly to the TIA for disposal.
- Clean water and snow will be managed such that they do not contribute to potentially poor quality water and be diverted to maintain natural drainage networks as much as possible.
- Non-contact water will be diverted around infrastructure, as much as feasible, and directed to the existing drainage networks.

- CWP storage capacity, freshet flows and expected storm event volumes will be determined based on site specific conditions. The sizing and design of these facilities is such that they can hold water during unusual storm events and contain freshet flows for prescribed periods.
- Waters intended for discharge directly from either the water control ponds or the TIA to the environment will be sampled for, and meet, applicable requirements under the MMER, water licences and/or surface leases administered pursuant to the Territorial Lands Act.
- Soil, snow and water contaminated with diesel fuel, aviation gasoline, jet fuels and/or gasoline will report to the landfarm. Treated water from the snow or clean water pond will only be removed for discharge to the tundra only once sample analysis has confirmed the quality is suitable for release to the environment. If water does not meet discharge criteria following treatment, the water will be transferred to the TIA for disposal. Soil collected from the landfarm will either be disposed of underground or at the TIA.
- The bulk fuel storage facilities and all transfer-related equipment will be routinely inspected and repairs (if required) carried out promptly.
- High quality ANFO explosives have been selected for blasting operations. The explosive product may be in the form of prills, emulsion, or be prepackaged. Different forms of the product may be used depending on the particular circumstances of use. Industry best practices will be employed to maximize source control and blast efficiency so as to minimize the potential for blasting product or blasting residues to occur in downstream waters.
- Dust suppression as appropriate will be applied to roadways to minimize dust from ore and waste rock haulage, site road traffic, and road maintenance (grading) when ambient air temperatures permit.
- Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable methods according to Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2016).
- During temporary closure the following will take place to protect freshwater sediment quality:
  - physical, chemical and biological monitoring and treatments will continue in accordance with the Project licences and permits.
  - Fuel, hazardous wastes and explosives will be properly stored or removed from site.
  - Waste rock and ore piles and tailings facilities as well as dams, roads and pipelines will be inspected and maintained.
  - Surface water management and sediment and erosion control will continue as needed.

5.5.3.3 Proposed Monitoring Plans and Adaptive Management

A Phase 2 Aquatic Effects Monitoring Plan (Volume 8, Annex 21) will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring the freshwater environment at locations potentially affected by the Project and at reference areas well away from Project activities; and
- monitoring freshwater water quality, sediment quality, and aquatic biology.

Regular inspections of water management facilities will be conducted by on-site Environmental Personnel.

There will be a Surveillance Monitoring Program that will be outlined in the future Type A Water License. This monitoring program will cover all of the site compliance monitoring required for the management and release of water from all Project infrastructure.

Adaptive management and corrective actions will be determined on a case-by-case basis. The actions may include modifications to existing mitigation and management measures or installation of additional control measures. Indications of the need for corrective actions and additional control measures may include:

- non-compliant observations or trends from the Surveillance Monitoring Program; or
- the observations of negative effects to the freshwater environment in the AEMP.

5.5.4 Characterization of Potential Effects to Freshwater Sediment Quality

Potential effects of the Project on freshwater sediment quality are characterized in this section. Specific mitigation and management measures are considered for each potential effect, and if the implementation of mitigation measures eliminates a potential effect, the effect is eliminated from further analyses. Project residual effects are the effects that remain or persist after mitigation and management measures are taken into consideration. If the proposed mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination. Residual effects of the Phase 2 Project can occur directly or indirectly. Direct effects result from direct interactions between Project activities and freshwater sediment quality. Indirect effects can occur when the primary effect is to another component of the environment (e.g., freshwater water quality), which can lead to secondary or indirect effects on freshwater sediment quality. The characterization of potential effects considers both the incremental effects of Phase 2 developments and activities as well as the overall effects from all components of the Hope Bay Development.

5.5.4.1 Potential Effects from Site Preparation, Construction, and Decommissioning

The disturbance of the landscape through site preparation and the construction of infrastructure such as AWRs and pads could affect freshwater sediment quality through physical contact and runoff. Physical contact with sediments could cause the mobilization and redistribution of sediments which could alter the particle size distribution, and consequently affect the concentrations of metals, organic material, and pollutants in sediments. Runoff can introduce metals, nutrients, hydrocarbons, and suspended sediments into freshwater environments; these can interact with sediments to cause shift from baseline conditions or a degradation of sediment quality. Potential effects of runoff on sediment quality are mainly indirect, resulting from runoff water interacting with water quality, which in turn could interact with sediment quality.

The primary goal of runoff and sedimentation control strategies will be to prevent soil, sediments, and particulate matter from entering the receiving environment. The existing Doris Project has demonstrated that erosion and sedimentation control measures are effective (as evaluated in the Doris AEMP), including the implementation of additional control measures on a case-by-case basis. Although identified mitigation and best management strategies (Section 5.5.3) are effective in minimizing erosion, sedimentation, and potential siltation in the receiving environment, these strategies may not fully prevent all surface runoff and sediment transport. Changes to water quality during construction and decommissioning activities will be monitored to ensure drainage and erosion controls are effective.

Characterization of Phase 2 Potential Effect

The Phase 2 site preparation, construction, and decommissioning activities include the development of additional pads, laydown areas, ore stockpiles, and waste rock storage areas in the Madrid South and Boston areas, as well as the construction of the AWRs. The in-water construction of the Boston discharge pipeline in Aimaokatalok Lake is also considered as a potential effect because the deployment of concrete anchors for the pipeline could temporarily re-suspend sediments and change the particle size distribution, which could alter metal concentrations in sediments.

Although the mitigation and management measures to control erosion, runoff, and sedimentation are known to be effective, the potential for residual effects from construction and decommissioning activities on freshwater water quality was identified (see Volume 5, Section 4). The residual effects to water quality were predicted to be localized, short-term in duration, and occurring intermittently during snowmelt and large precipitation events. The effects of runoff during site preparation, construction, and decommissioning on freshwater water quality were further characterized as reversible and ultimately rated as not significant (Volume 5, Section 4). Because runoff is expected to interact primarily with water quality (which in turn interacts with sediment quality) and the residual effect of runoff on water quality was rated as not significant, there is not anticipated to be any potential residual effect of runoff from site preparation, construction, and decommissioning on freshwater sediment quality.

The physical in-water works related to the installation of culverts or bridges where AWRs cross streams and the installation of a discharge pipeline in the southwestern arm of Aimaokatalok Lake could affect sediment quality by mobilizing sediments and altering the particle size distribution and sedimentation patterns. Streams in which culverts or bridges could be installed include Glenn, Ogama, Wolverine, Trout, and Stickleback outflows, and Patch, Doris, and Aimaokatalok inflows, as well as Roberts Bay Inflow and Boulder Creek (see Table 6.5-5 in Volume 5, Section 6 for specific locations of these streams). The potential effects of the installation of culverts, bridges, or the discharge pipeline on sediment quality are considered to be potential residual effects and are further characterized in Section 5.5.5.

Characterization of Hope Bay Development Potential Effect

Construction of a substantial portion of the infrastructure at Roberts Bay and Doris has already been completed, and does not present a potential effect from construction activities. Similarly, construction at Madrid North under the Type “B” licence will be completed as authorized. These past residual effects were negligible, because no construction-related effects were observed in Doris as evaluated under the Doris AEMP (e.g., ERM 2016). As a result, any localized, short-term changes in water quality from the construction of existing and permitted infrastructure will not coincide with the proposed Phase 2 activities, and there is minimal potential for a cumulative effect across the Hope Bay Development. Therefore, the residual effects from site preparation and construction activities for the Hope Bay Development are anticipated to be the same as the Phase 2 residual effects.

However, decommissioning activities will occur throughout the Project areas, and will include the decommissioning of infrastructure at Roberts Bay and Doris. Effective mitigation and management measures will be applied, but the potential for residual effects from decommissioning activities on freshwater water quality (including secondary effects to sediment quality) remains. Given that runoff is expected to interact primarily with water quality, which in turn interacts with sediment quality, and the residual effects of runoff on water quality were rated as not significant for the Hope Bay Development (Volume 5, Section 4), there are not anticipated to be any potential residual effects of runoff from site preparation, construction, and decommissioning on freshwater sediment quality for entire development.

5.5.4.2 Potential Effects from Site and Mine Contact Water

Water and sediment quality are closely related because metals, nutrients, and organic material are continuously exchanged between the water column and sediments depending on the specific environmental conditions and the properties of the constituents of water or sediments. The potential effects from site and mine contact water on sediment quality were mainly informed by the quantitative prediction from the Water and Load Balance Model (Volume 3, Appendix V3-2D). The potential residual effects from site contact water and mine contact water were characterized together because the quantitative model considered the contributions of both site and mining activities for predicting the effects of the Hope Bay Project on the aquatic environment.

The potential for residual effects from site contact water are predicted to be reduced by the application of the mitigation and management measures outlined in Section 5.5.3. Once the water management systems are constructed, the majority of site contact water will be intercepted and prevented from contacting the freshwater receiving environment (Water Management Plan [Volume 8, Annex 8]). Intercepted site contact water will be stored in CWPs and discharged to the marine environment via the TIA (Doris, Madrid North, and Madrid South areas) or treated and discharged to Aimaokatalok Lake (Boston area). These water management and treatment measures are included in the water balance model, which improves the realism and accuracy of the model (Appendix V3-2D). During construction and decommissioning of Project infrastructure, some site contact water will report to the freshwater receiving environment when the water management system is not operational. Furthermore, runoff from some pads and laydown areas will not be diverted to the TIA or Boston water treatment plant; site contact water from these locations will be collected in sumps and discharged if the contact water meets permit conditions for water quality. Site contact water will not be released to the receiving environment unless it meets the water quality criteria outlined in applicable water licences.

Throughout all areas of the Project, the release of site contact water has the potential to transport suspended sediments into the receiving environment. The application of the mitigation and management measures associated with suspended sediments, outlined in Section 5.5.3, are predicted to be effective reducing the quantities of transported suspended material. However, there is the potential for alteration of suspended sediment concentrations in the receiving environment prior to the completion of the water management infrastructure and during normal, permitted releases of contact water from sumps. Adherence to the water licence criteria and application of the proven mitigation and management measures were predicted to maintain suspended sediment concentrations below CCME water quality guidelines for the protection of aquatic life (i.e., increases of 25 mg/L short-term and 5 mg/L long-term for the TSS indicator), but may be associated with localized, temporary increases above baseline conditions. These potential increases in suspended sediments are not expected to cause significant deposition of sediments onto lake or stream beds, and there are not anticipated to be residual effects to sediment particle size composition.

Residual effects from mine contact water, which is defined as the runoff from waste rock and ore stockpiles, underground water, and water from ore processing mills, are also expected to be reduced by mitigation and management, including water treatment. The interception of mine contact water prior to contact with the freshwater environment is a fundamental measure in the design of the Phase 2 Project. In the Boston area, mine contact water will be treated and discharged to Aimaokatalok Lake. This discharge is modelled in the water balance model, and assessed as a potential residual effect. After decommissioning and reclamation of Project infrastructure, runoff from the TIA (Doris area) and TMA (Boston area) will be directed to the freshwater environment. Therefore, there is a potential residual effect in the Post-closure phase from mine contact water.

The chemical constituents in the Water and Load Balance Model included inorganic nitrogen species (i.e., ammonia, nitrite, and nitrate) and metals (e.g., arsenic, copper, mercury, and iron), which are indicators of sediment quality as well as water quality. The timing of specific infrastructure and activities (such as the commissioning of waste rock storage areas) is explicitly included in the model.

Details of the predicted effects to freshwater water quality from site and mine contact water using the quantitative water balance model (Water and Load Balance, Appendix V3-2D) are provided in Volume 5, Section 4. Effects to sediment quality are not incorporated into the quantitative model, but are informed by the results of the quantitative water quality assessment.

Characterization of Phase 2 Potential Effects

Boston Area

The assessment of effects of site and mine contact water on freshwater water quality predicted that concentrations of some metals and nutrients would increase above baseline concentrations in the waters of Stickleback Lake, Aimaokatalok Lake, and the Koignuk River (Volume 5, Section 4). In most cases, metals and nutrients were predicted to be elevated above baseline levels during all project phases; however, some metals or nutrients were elevated only during specific phases (e.g., arsenic, antimony, and nickel in the eastern arm of Aimaokatalok Lake were elevated only during Post-closure when runoff from the TMA is expected to affect water quality; Volume 5, Section 4).

Although some metal and nutrient concentrations were predicted to increase above baseline levels, only a small fraction of metal concentrations were predicted to increase above CCME water quality guideline thresholds: aluminum, chromium, copper, iron, selenium, in Stickleback Lake. These threshold exceedances were predicted to occur only during the under-ice season, and, as explained in Volume 5, Section 4, the water quality model included an overly conservative cryo-concentration function that overestimated under-ice metal concentrations compared to actual differences between open-water and under-ice concentrations observed during baseline sampling programs. Therefore, predictions of water quality concentrations that were greater than assessment thresholds likely occurred as a result of a modelling artefact. In addition, the predicted exceedances occurred in both the modelled baseline and predicted cases for aluminum, chromium, copper, and iron, which indicates that the predicted changes in the concentrations of these parameters in Stickleback Lake are not the result of Project activities and infrastructure.

Lake, river, and stream sediments in the Boston area are naturally metal-rich, and baseline studies have shown that sediment metal concentrations occasionally exceed CCME sediment quality guidelines for arsenic, chromium, and copper (Section 5.2.4). These and other metals may increase relative to baseline concentrations in the waters of Stickleback Lake, arsenic and other metals may increase in the water in at least a portion of Aimaokatalok Lake, and copper and other metals may increase in Koignuk River waters. The water quality model predicted that inorganic nitrogen species including ammonia, nitrate, and nitrite may also increase in the waters of each of these Boston area waterbodies, and this in turn could affect sediment quality. These increases in metals and nutrients were considered to be potential residual effects in the analysis of freshwater water quality (Volume 5, Section 4). Constituents such as metals and nutrients are continuously exchanged between sediments and overlying waters. Therefore, it follows that predicted increases in water quality parameters such as metals and nutrient may cause residual effects to sediment quality as well. Residual effects to sediment quality in the Boston area are further characterized in Section 5.5.5.

Madrid Area

In the Madrid area lakes, the assessment of effects of site and mine contact water on freshwater water quality predicted that concentrations of some metals would increase above baseline concentrations in the waters of Windy, Wolverine, Patch, P.O., and Ogama lakes (Volume 5, Section 4). With the exception of under-ice copper concentrations in Wolverine Lake, the maximum predicted increases were substantially less than applicable water quality guidelines. The predicted copper concentrations that were greater than guidelines in Wolverine Lake were likely the result of a modelling artefact from the overly conservative cryo-concentration assumptions (Volume 5, Section 4).

Nearly all predictions of metal concentrations that were elevated above baseline (but less than CCME guidelines) in Madrid area lakes occurred during the Post-closure phase. After the closure and decommissioning of infrastructure, the following were predicted to influence water quality in Madrid area lakes: small volumes of groundwater (0.1 m^3/d) slowing seeping to Windy Lake from the closed Madrid North mine (travel time greater than 1,000 years; Appendix V3-4B); runoff from decommissioned pad and stockpile areas from the Madrid South site into Wolverine Lake; and the cessation of mine contact water management and decommissioning of associated infrastructure (such as CWPs at Madrid North and Madrid South) near Patch, P.O., and Ogama lakes.

Freshwater sediments in the Madrid area are naturally metal-rich, and baseline studies show that sediment metal concentrations occasionally exceed CCME sediment quality guidelines for arsenic, chromium, and copper (Section 5.2.4). The predicted post-closure increases in metals in Windy, Wolverine, Patch, P.O., and Ogama lakes were considered to be potential residual effects in the analysis of freshwater water quality (Volume 5, Section 4). Because metals are continuously exchanged between sediments and overlying waters, it follows that predicted increases in metal concentrations in the water column may also cause residual effects to sediment quality. Residual effects to sediment quality in the Madrid area are further characterized in Section 5.5.5.

Doris Area

The potential for residual effects to freshwater water quality in the Doris area were identified in the screening of the predictions of the water balance model. Site and mine contact water have the potential to interact with Doris Lake through indirect flow from the Madrid North and Madrid South sites via Ogama Lake, runoff from infrastructure at the Doris site, runoff from the TIA in the Post-closure phase, and groundwater interactions with the Doris mine.

Several metals were predicted to increase in the waters of Doris Lake and in downstream Little Roberts Lake relative to baseline concentrations during various phases of the Project, but all predicted concentrations were less than assessment thresholds (i.e., CCME water quality guidelines). Predicted concentrations were highest in the Post-closure phase when the runoff from the TIA joins the natural flows in the Doris catchment (Volume 5, Section 4).

The sediments of the Doris area are naturally metal-rich, and baseline data show that concentrations of arsenic, chromium, and copper in sediment samples have frequently been higher than CCME sediment quality guidelines (Section 5.2.4). The predicted increases in metal concentrations in Doris and Little Roberts lakes were considered to be potential residual effects in the analysis of freshwater water quality (Volume 5, Section 4). Metals are continuously exchanged between sediments and overlying waters; therefore, it follows that predicted increases in metal concentrations in the water column may cause residual effects to sediment quality as well. Residual effects to sediment quality in Doris and Little Roberts lakes are further characterized in Section 5.5.5.

Characterization of Hope Bay Project Potential Effect

Potential effects from the Hope Bay development were incorporated in the water balance model. Mining operations at Doris will continue until Project Year 3 of Phase 2 under the current mine plan. These potential effects include components of the site and mine water contact interaction groups, including the following effects during the Operation, Closure, and Post-closure phases:

- runoff from pads and infrastructure at the Doris site;
- tailings from the Doris mine deposited in the TIA; and
- mine water from the Doris mine.

Therefore, the potential residual effects from the Doris development have already been assessed within the Phase 2 assessment for the Operation, Closure, and Post-closure phases. Site contact water during the construction of Doris infrastructure may have had the potential for residual effects to freshwater sediment quality. These potential residual effects would have included the runoff of metals and hydrocarbons from disturbed areas of the landscape, pads areas, and laydown areas. However, the current Hope Bay water monitoring program, which includes surveillance monitoring of contact water and AEMP monitoring in the receiving environment, has not identified any Project-related effects to the sediment quality of Doris Lake or downstream in Doris Creek and Little Roberts Lake (ERM 2016). As a result, no incremental residual effects on sediment quality from the Hope Bay Development from site and mine contact water were identified beyond the effects already described for the Phase 2 Project.

5.5.4.3 Potential Effects from Quarries and Borrow Pits

Characterization of Phase 2 Potential Effect

Runoff is the primary pathway for interaction between quarries and the freshwater environment. As a result, minimizing the transport of material in runoff and reducing the quantity of runoff will be the primary goal of mitigation and management efforts (Section 5.5.3). The potential effects from quarries and borrow pits will be minimized by the following specific measures:

- only geochemically suitable material will be used for quarries and borrow pits;
- equipment will be maintained and repaired to avoid potential leaks of fuels and petroleum hydrocarbons;
- local drainage patterns will be maintained and the flow of water into the quarry minimized by the diversion of non-contact water around quarries; and
- quarries and borrow pits will have water collection and control infrastructure (Hope Bay Project Quarry Management and Monitoring Plan (Volume 8, Annex 17)).

If the runoff is turbid but chemically-unaltered, it will be allowed to infiltrate into the ground if it meets permit discharge criteria. By minimizing the volume of water within quarries and collecting water within the quarries, suspended sediments and sediment-associated metals can be settled in sump and will not contact the freshwater environment. Due to the mitigation and management measures, including monitoring and adaptive management of quarry runoff, no residual effects from quarries and borrow pits were predicted for freshwater sediment quality for the Phase 2 development.

Characterization of Hope Bay Development Potential Effect

Existing quarries and borrow pits for the Doris site have been operating with no detected effects to sediment quality in the freshwater environment. The mitigation and management measures applied to quarries and borrow pits have been shown to be effective as evaluated by the Doris AEMP. Therefore, no residual effects from the overall Hope Bay development are predicted.

5.5.4.4 Potential Effects from Explosives

Characterization of Phase 2 Potential Effect

Potential residual effects from explosives may occur from the transport, storage, and use of ANFO explosives for mining and construction. The potential effects from transport and storage were considered fully mitigated by the following measures:

- storage and transport in accordance with the *Explosives Act* (1985c);
- the handling and manufacture of explosives by licensed operators;
- interception and collection of runoff from explosive storage and manufacture facilities prior to contact with the freshwater environment; and
- the application of BMP for blasting and the handling of explosives to minimize residues and spillage.

Runoff and seepage of blasting residues on mine workings, waste rock, tailings, and run-of-quarry material may affect water quality, which could in turn affect sediment quality. The water balance model includes blasting residues, and provides quantitative predictions of nitrogenous residues (ammonia, nitrite, and nitrate) in the freshwater environment (Appendix V3-2D). The predicted concentrations of all nitrogenous species were less than assessment thresholds throughout the Project area. The water balance model predicted that the concentrations of nitrogenous compounds may increase relative to baseline conditions in Stickleback and Aimaokatalok lakes and in the Koignuk River (Volume 5, Section 4). These predicted increases were, at least partially attributable to blasting residues in site and mine contact water. Increases in nitrogenous compounds in the water could affect the concentrations of these nutrients in sediments as well as the concentration of TOC in sediments if introduced nutrients stimulate the productivity of freshwater systems.

Although explosives were considered a potential residual effect for the water quality analysis (Volume 5, Section 4), they were ultimately characterized as not significant. Given that explosives would be expected to interact directly with water quality, but indirectly with sediment quality (because sediment quality changes would only be expected to occur if changes to water quality were apparent), and the residual effect of explosives on water quality was rated as not significant, there is not expected to be a residual effect of explosives on sediment quality. Moreover, ammonia, nitrite, and nitrate are generally highly soluble, so these would likely remain in solution and would be expected to affect water quality more than sediment quality.

The effect from blasting residues on sediment quality through the aerial deposition pathway is predicted to be negligible (see Section 5.5.4.7). The majority of explosives use will occur underground. Surface blasting for quarrying and construction will be designed to minimize the generation of dust.

Characterization of Hope Bay Development Potential Effect

Construction and mining activities throughout the Hope Bay Development require the use of explosives. Mitigation and management measures have been effective for the existing Doris development, and no explosives-related changes in the concentration of nitrogen compounds have been observed in the current Doris AEMP (ERM 2016). The results of the water balance model predicted an increase in the concentrations of ammonia, nitrate, and nitrite in waterbodies near the Boston site (which is associated with the Phase 2 Project), but no increase in nitrogen species were predicted for the Madrid and Doris area lakes. Therefore, Approved projects are not expected to introduce nitrogen species into freshwater systems. The potential changes in nitrogen compound concentrations resulting from the use of explosives in the overall Hope Bay Development were predicted to be relatively small, based on the observed performance of the mitigation and management measures and the small magnitude of predicted effects in the water balance model. As was concluded for the Phase 2 Project, there is not expected to be a residual effect of explosives use on sediment quality in the Hope Bay Development.

5.5.4.5 Potential Effects from Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group activities will interact with the freshwater environment through runoff and aerial deposition (for PAH, see Section 5.5.4.7). The mitigation and management measures for runoff are focused on preventing hydrocarbons from being transported in runoff (Section 5.5.3). Fuels, oils, and PAH will be managed as described in the Oil Pollution Prevention Plan / Oil Pollution Emergency Plan (Volume 8, Annex 3), the Hope Bay Project Spill Contingency Plan (Volume 8, Annex 4), and the Hope Bay Project Hazardous Waste Management Plan (Volume 8, Annex 15). The majority of runoff from site pads, laydown areas, and waste management areas will be directed to the water management infrastructure and not discharged to the freshwater environment. This intercepted water will be diverted to the TIA or the Boston Water Treatment Plant (WTP). Otherwise, runoff will be collected in sumps and discharged only if it meets water quality standards under applicable water licences.

For the aerial deposition of PAH, the primary mitigation measure will be the efficient operation of the incinerator (Incineration Management Plan; Volume 8, Annex 16). The operation of the incinerator will comply with Nunavut standards (Nunavut Department of Environment 2012), *Canada-Wide Standards for Dioxins and Furans* (CCME 2001a), and *Canada-Wide Standards for Mercury Emissions* (CCME 2000). The operation of the incinerator includes the following management measures:

- waste segregation (i.e., materials that are unsuitable for incineration, e.g., chlorinated plastics, will be diverted to alternate waste disposal facilities);
- properly trained personnel for incinerator operations; and
- periodic stack testing and adaptive management to ensure compliance with standards.

Project activities related to fuels and other petroleum hydrocarbons were predicted to have negligible effects on freshwater sediment quality. The mitigation and management measures were considered effective at minimizing the potential for effects on the freshwater environment during normal operations. No hydrocarbon compounds or sediments from Project activities at the sites, laydown areas, fuel areas, or waste storage areas were predicted to reach the freshwater environment because of BMPs for machinery operation, maintenance, and fueling, and the direction of runoff carrying potential compounds to the water management facilities. The incinerator will be operated according to guidelines and standards, and therefore negligible aerial deposition of PAH into the freshwater environment is expected. Therefore, no residual effects from fuels, oils, and PAH are predicted on freshwater sediment quality. This prediction is applicable to both the incremental effects of the Phase 2 Project as well as the overall Hope Bay Development.

5.5.4.6 Potential Effects from Treated Sewage Discharge

Treated domestic sewage has the potential to interact with the freshwater environment through the discharge pathway. As described in Section 5.4.1, treated sewage from Doris, Madrid North, and Madrid South areas will be discharged to the TIA, and subsequently to the marine environment. Treated domestic sewage in the Boston area may be discharged to the tundra prior to the commissioning of the Boston WTP and to Aimaokatalok Lake with combined effluent from the Boston WTP when operational.

Characterization of Phase 2 Potential Effect

The Phase 2 potential effect from treated sewage discharge is restricted to the Boston area. Domestic sewage from other Project areas will be discharged to the marine environment via the TIA, and therefore no potential exists during normal operations for contact between treated sewage and the freshwater environment.

The Boston domestic treated sewage may be discharged to the tundra during Construction and Closure phases, and was therefore not considered to interact with the freshwater environment. Only the discharge of treated sewage into Aimaokatalok Lake during Operation has the potential for residual effects to freshwater sediment quality. The water balance model included discharge from the sewage treatment plant. The effluent concentrations of nitrite, nitrate, and chromium were predicted to be greater than CCME water quality guidelines (see Volume 5, Section 4).

Treated sewage will be discharged into Aimaokatalok Lake via a combined outfall with the WTP, and will be effectively mixed in the receiving environment using a diffuser (Appendix V5-4K). The near-field mixing model predicted rapid mixing within 3 m of the outfall, and the predicted receiving environment concentrations of nitrite, nitrate, and chromium were less than their applicable assessment thresholds (i.e., water quality guidelines; see Volume 5, Section 4). Beyond the near-field mixing environment, the potential effects on water quality from the discharge of treated sewage were predicted by the water balance model, and discussed as part of the characterization of potential site and mine contact water effects in Section 5.5.4.2. Therefore, no potential residual effects from sewage discharge were identified for Phase 2, beyond the effects already integrated and identified in Section 5.5.4.2.

Characterization of Hope Bay Development Potential Effect

The discharge of domestic sewage to the marine environment via the TIA from the Doris, Madrid North, and Madrid South areas would not be expected to interact with the freshwater environment. Only sewage discharge in the Boston area can potentially affect the freshwater environment, and the Boston area development is associated with the Phase 2 Project. Therefore, other than the potential effects from the Phase 2 Project, there are no additional residual effects to consider from Existing and Permitted projects within the Hope Bay Development.

5.5.4.7 Potential Effects from Dust Deposition

The Air Quality Management Plan (Volume 8, Annex 19) describes the specific mitigation measures that will be followed to ensure that dust generation and transport is minimized. As well, the use of geochemically suitable materials for the construction of roads and infrastructure and the adherence to the Incineration Management Plan (Volume 8, Annex 16) will ensure that the potential generation of airborne matter is minimized. Despite these mitigation measures, the results of air quality modelling work (Volume 4, Section 2) predicted that Phase 2 Project activities will generate dust that could potentially be deposited into the freshwater environment.

Characterization of Phase 2 Potential Effects

The quantitative air quality model results provided predictions of airborne dust deposition rates attributable to the Phase 2 Project in combination with Approved projects (Volume 4, Section 2). Potential dust sources such as construction activities, operation of the TIA, and vehicle traffic were incorporated into the model. Data extracted from the interpolated air quality model were used to obtain lake-specific average annual maximum deposition rates; these are summarized in Table 5.5-5. Average annual maximum dust deposition rates within the LSA lakes during Construction and Operation phases ranged from 9 to 18 g/m^2/yr (Table 5.5-5).

Table 5.5-5. Calculated Average Annual Dust Deposition Rates in LSA Lakes

Lake	**Average Annual Maximum Deposition Rate (g/m^2/yr)**	
Project Phase:	**Construction Phase**	**Operation Phase**
Doris Lake	11	11
Ogama Lake	9	9
Patch Lake	11	12
Windy Lake	10	11
P.O. Lake	9	9
Aimaokatalok Lake	9	9
Stickleback Lake	18	17
Trout Lake	9	10

For the purposes of this assessment, it was assumed that all dust that is deposited on a lake surface would reach the lakebed. The particle sizes considered for the dust deposition model are generally smaller than 100 µm in diameter. In terms of sediment particle sizes, deposited dust would be classified as clay, silt, or fine sand, which are relatively small particles that could remain in suspension (size classes shown in Table 9.2-3). Therefore, the assumption that all deposited dust would reach the lakebed is conservative.

For the analysis of sediment quality (e.g., metals, TOC, nutrients), the uppermost 2 to 3 cm of the sediments are typically sampled (e.g., Appendices V5-3I and V5-3J). The density of lake sediments generally ranges from 1,000,000 to >2,000,000 g/m3 (Last and Smol 2006). Assuming a sediment density of 1,500,000 g/m3, a 3 cm-thick layer of sediment occupying a 1 m2 area of the lakebed would contain approximately 45,000 g of sediment. Considering the range of deposition rates in LSA lakes, the average annual deposition of 9 g onto 45,000 g of sediment would represent an annual increase of 0.02%, and the average annual deposition of 18 g onto 45,000 g would represent an annual increase of 0.04%. Over the 17-year Construction and Operation timeframe of Phase 2, this would amount to less than a 1% increase. These estimated increases are negligible from baseline levels and would be within the margin of error of sediment quality analyses. Therefore, dust deposition would not cause a measurable change in sediment quality in the LSA lakes, and dust deposition is not further assessed as a residual effect.

<u>Characterization of Hope Bay Project Potential Effect</u>

The dust modelling results considered dust contributed by the Phase 2 Project as well as from Approved Projects. The dust inputs specific to the Phase 2 Project were not considered in isolation of other activities within the Hope Bay Development; therefore, the discussion of Phase 2 potential effects applies equally to the Hope Bay Development. Dust deposition is not expected to affect freshwater sediment quality, and is not further assessed as a residual effect for the Hope Bay Development.

5.5.5 Characterization of Residual Effects on Freshwater Sediment Quality

5.5.5.1 Definitions for Characterization of Residual Effects

To determine the significance of Project residual effect, each potential negative residual effect is characterized by a number of attributes consistent with those defined in of the EIS guidelines

(Section 7.14, Significance Determination for the Hope Bay Project; NIRB 2012). A definition for each attribute and the contribution that it has on significance determination is provided in Table 5.5-6.

Table 5.5-6. Attributes to Evaluate Significance of Potential Residual Effects

Attribute	Definition and Rationale	Impact on Significance Determination
Direction	The ultimate long-term trend of a potential residual effect - positive, neutral, or negative.	Positive, neutral, and negative potential effects on VECs are assessed, but only negative residual effects are characterized and assessed for significance.
Magnitude	The degree of change in a measurable parameter or variable relative to existing conditions. This attribute may also consider complexity - the number of interactions (Project phases and activities) contributing to a specific effect.	The higher the magnitude, the higher the potential significance.
Duration	The length of time over which the residual effect occurs.	The longer the length of time of an interaction, the higher the potential significance.
Frequency	The number of times during the Project or a Project phase that an interaction or environmental/ socio-economic effect can be expected to occur.	Greater the number times of occurrence (higher the frequency), the higher the potential significance.
Geographic Extent	The geographic area over which the interaction will occur.	The larger the geographical area, the higher the potential significance.
Reversibility	The likelihood an effect will be reversed once the Project activity or component is ceased or has been removed. This includes active management for recovery or restoration.	The lower the likelihood a residual effect will be reversed, the higher the potential significance.

For the determination of significance, each attribute is characterized. The characterizations and criteria for the characterizations are provided in Table 5.5-7. Each of the criteria contributes to the determination of significance.

Table 5.5-7. Criteria for Residual Effects for Environmental Attributes

Attribute	Characterization	Criteria
Direction	Positive	Beneficial
	Variable	Both beneficial and undesirable
	Negative	Undesirable
Magnitude	Negligible	No change on the exposed indicator/VEC
	Low	Differing from the average value for the existing environment to a small degree, but within the range of natural variation and well below a guideline or threshold value
	Moderate	Differing from the average value for the existing environment and approaching the limits of natural variation, but below or equal to a guideline or threshold value
	High	Differing from the existing environment and exceeding guideline or threshold values so that there will be a detectable change beyond the range of natural variation (i.e., change of state from the existing conditions)

Attribute	Characterization	Criteria
Duration	Short	Up to 4 years (Construction phase)
	Medium	Greater than 4 years and up to 17 years (4 years Construction phase, 10 years Operation phase, 4 years Reclamation and Closure phase)
	Long	Beyond the life of the Project
Frequency	Infrequent	Occurring only occasionally
	Intermittent	Occurring during specific points or under specific conditions during the Project
	Continuous	Continuously occurring throughout the Project life
Geographic Extent	Project Development Area (PDA)	Confined to the PDA
	Local Study Area (LSA)	Beyond the PDA and within the LSA
	Regional Study Area (RSA)	Beyond the LSA and within the RSA
	Beyond Regional	Beyond the RSA
Reversibility	Reversible	Effect reverses within an acceptable time frame with no intervention
	Reversible with effort	Active intervention (effort) is required to bring the effect to an acceptable level
	Irreversible	Effect will not be reversed

5.5.5.2 Determining the Significance of Residual Effects

Section 7.4 of the EIS guidelines provided guidance, attributes, and criteria for the determination of significance for residual effects (NIRB 2012). Also, the Canadian Environmental Assessment Agency's *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* (CEA Agency 1992) also guided the evaluation of significance for identified residual effects. The significance of residual effects is based on comparing the predicted state of the environment with and without the Project, including a judgment as to the importance of the changes identified.

<u>Probability of Occurrence or Certainty</u>

Prior to the determination of the significance for negative residual effects, the probability of the occurrence or certainty of the effect is evaluated. For each negative residual effect, the probability of occurrence is categorized as unlikely, moderate or likely. Table 5.5-8 presents the definitions applied to these categories.

<u>Confidence</u>

The knowledge or analysis that supports the prediction of a potential residual effect—in particular with respect to limitations in overall understanding of the environment and/or the ability to foresee future events or conditions—determines the confidence in the determination of significance. In general, the lower the confidence, the more conservative the approach to prediction of significance must be. The level of confidence in the prediction of a significant or non-significant potential residual effect qualifies the determination, based on the quality of the data and analysis and their extrapolation to the predicted residual effects. "Low" is assigned where there is a low degree of confidence in the inputs, "medium" when there is moderate confidence and "high" when there is a high degree of confidence in the inputs. Where rigorous baseline data were collected and scientific analysis performed, the degree of confidence will generally be high. Table 5.5-8 provides descriptions of the confidence criteria.

Table 5.5-8. Definition of Probability of Occurrence and Confidence for Assessment of Residual Effects

Attribute	Characterization	Criteria
Probability of occurrence or certainty	Unlikely	Some potential exists for the effect to occur; however, current conditions and knowledge of environmental trends indicate the effect is unlikely to occur.
	Moderate	Current conditions and environmental trends indicate there is a moderate probability for the effect to occur.
	Likely	Current conditions and environmental trends indicate the effect is likely to occur.
Confidence	High	Baseline data are comprehensive; predictions are based on quantitative predictive model; effect relationship is well understood.
	Medium	Baseline data are comprehensive; predictions are based on qualitative logic models; effect relationship is generally understood, however, there are assumptions based on other similar systems to fill knowledge gaps.
	Low	Baseline data are limited; predictions are based on qualitative data; effect relationship is poorly understood.

Residual effects identified in the Project-related effects assessment are carried forward to assess the potential for cumulative interactions with the residual effects of other projects or human activities and to assess the potential for transboundary impacts should the effects linked directly to the activities of the Project inside the Nunavut Settlement Area (NSA), which occurs across provincial, territorial, international boundaries or may occur outside of the NSA.

Determination of Significance

A description of how residual effects were designated as "not significant" or "significant" is provided in this section. Although general guidelines can be followed for the determination of significance, it is not practicable to outline all possible permutations of attribute criteria that would result in an effect being designated as "not significant" or "significant". Rather, residual effects were assessed on a case-by-case basis using the criteria outlined below as well as professional judgement to ultimately assign a significance rating.

Not Significant: A residual effect rated as "not significant" may result in a slight to moderate decline in freshwater sediment quality within the zone of influence of the Project relative to reference conditions during the life of the Project, but sediment quality would generally be expected to return to baseline conditions after Project closure. Non-significant residual effects on sediment quality are not considered to have serious consequences (e.g., sediments metals increase slightly from baseline concentrations or sediment particle size composition changes during the life of the Project but all sediment indicators return to baseline conditions during Closure and Reclamation or Post Closure). The specific attribute criteria leading to a designation of an effect as "not significant" can be variable.

Significant Effect: A residual effect rated as "significant" is expected to result in the degradation of freshwater sediment quality within the LSA or extending into the RSA relative to reference conditions, and is irreversible or requires some effort to reverse. Significant residual effects on sediment quality are consequential (e.g., sediments are contaminated and can no longer support their ecosystem function). Regional management actions such as research, monitoring, and recovery initiatives may be required should changes to freshwater sediment quality exceed acceptable thresholds. Specific criteria of attributes such as duration, frequency, geographic extent, and reversibility that lead to a residual effect being considered "significant" can be variable.

5.5.5.3 Characterization of Residual Effect for Freshwater Sediment Quality

<u>Site Preparation, Construction, and Decommissioning</u>

Phase 2 Potential Effect

There exists the potential for residual effects to freshwater sediments through the in-water or near-water works required for the installation of the discharge pipeline in Aimaokatalok Lake as well as the installation and decommissioning of culverts and bridges in or over streams that will be crossed by AWRs. The installation and decommissioning of infrastructure in Aimaokatalok Lake and in various streams (listed in Section 5.5.4.1) may cause some temporary and localized disturbance and redistribution of sediments. A change in the particle size distribution of sediments and in sedimentation patterns could represent a deviation from baseline particle size composition and sediment metal concentrations.

A summary of the characterization and assessment of the residual effects of physical disturbances associated with site preparation, construction, and decommissioning is provided in Table 5.5-9. The residual effects from in-water works may result in a redistribution of sediments, but since there will be no net increase in potentially adverse sediment constituents such as metals or hydrocarbons because of the use of geochemically inert materials for construction, the direction of the residual effect is considered to be *variable*. Any residual effects are expected to be *low* in magnitude because the redistribution of existing loads of metals or pollutants is not expected to cause any change in sediment quality indicators beyond what is expected from the natural variation and heterogeneity of sediment quality within a waterbody. The duration of the potential residual effects is expected be *short*, because the potential physical disturbance will only occur during a relatively short window of time during the Construction or Closure phases, and the suspended sediments will resettle following the infrastructure installation. The frequency of the potential effect is predicted to be *intermittent*, because potential sediment mobilization could occur periodically during the installation or decommissioning of in-water infrastructure. The potential residual effects are expected be confined to the LSA as only sediments within Aimaokatalok Lake or specific streams crossed by AWRs will be affected. Within Aimaokatalok Lake, the residual effect is expected to be highly localized to the footprint of the cement ballast that anchors the pipeline, and within the affected streams, the effect will be largely confined to the footprint of the culver or bridge. Any residual effects are predicted to be *reversible* once in-water installation or decommissioning activities are completed, because in the absence of physical disturbances sediments will be re-worked by natural physical processes such wind-driven mixing or stream flow (Table 5.5-9).

The probability of occurrence of residual effects from in-water works is considered to be *likely*. The overall significance of the effects of physical disturbances associated with in-water works is **not significant** because of the variable direction and low magnitude of the residual effect, the confinement of the effect within a small fraction of the overall freshwater LSA, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *high* (Table 5.5-9).

Hope Bay Project Potential Effect

The potential residual effects identified for freshwater sediments from site preparation, construction, and decommissioning activities are mainly associated with Phase 2 Project infrastructure. The installation of the discharge pipeline in Aimaokatalok Lake and the installation of culverts or bridges in streams associated with AWR crossings are being undertaken as part of the Phase 2 Project. Other than the potential effects from Phase 2, the only known residual effects to freshwater sediments from in-water or near-water works related to site-preparation, construction, and decommissioning activities in the Hope Bay Development are those associated with the decommissioning of existing near or in-water infrastructure such as culverts and bridges. These activities are expected to incrementally add to the potential residual effects characterized for the Phase 2 activities. The overall characterization of effects for the entire Hope Bay Development (Table 5.5-10) is identical to the characterization provided for the Phase 2 Project in isolation (Table 5.5-9). The overall significance of the effects of site preparation, construction, and decommissioning activities on freshwater sediment quality in the Hope Bay Development is **not significant** (Table 5.5-10).

<u>Site and Mine Contact Water</u>

Phase 2 Potential Effect

Residual effects from site and mine contact water on freshwater sediment quality were informed by the analysis of effects to freshwater water quality (Volume 5, Section 4), which was based on the quantitative water balance model (Volume 3, Appendix V3-4F). Metals, nutrients, and organic material are continuously exchanged between the water column and sediments depending on the specific environmental conditions and the properties of the constituents of the water or sediments. It is conservative to assume that increases in metal and nutrient concentrations in the water could lead to increases in metal and nutrient concentrations in sediments, however this not necessarily the case. For example, at the Ekati Diamond Mine in Canada's Northwest Territories, concentrations of arsenic, barium, boron, nickel, selenium, and uranium have increased in lake waters with no corresponding increase in the lake sediments (ERM 2015b).

The freshwater water quality assessment of effects concluded that there may be increases in the concentrations of some metals and nitrogen species above baseline levels in the waters of Stickleback, Aimaokatalok, Windy, Wolverine, Patch, P.O., Ogama, Doris, and Little Roberts lakes and in the Koignuk River resulting from the discharge, runoff, and seepage of site and mine contact water (Volume 5, Section 4). Based on these predictions, it is conservative to assume that metal and nutrient concentrations could also increase in the sediments of these waterbodies. Therefore, the magnitude of this *negative* residual effect to sediments was predicted to be *moderate* as the increases predicted for water quality metal and nutrient concentrations were generally modest. Many of the predicted increases were predicted to remain throughout the Post-closure phase, and were therefore concluded to be *long*-term in duration. The frequency of inputs of site and mine contact water was characterized as *intermittent to continuous*. However, the geographic extent of the residual effects from site and mine contact water was concluded to be restricted to the *LSA* (Table 5.5-9).

The residual effects from site and contact water were characterized as *irreversible* (Table 5.5-9). The long-term effects associated with runoff from the TIA, TMA, and reclaimed Project infrastructure were predicted to continue throughout the Post-closure phase. As discussed in the Water and Load Balance Model report (Volume 3, Appendix V3-4F), interactions between decommissioned Project infrastructure may continue for hundreds of years as equilibria are reached in groundwater interactions between closed mine works and nearby lakes.

The residual effects were characterized as *likely* with a *medium* degree of confidence. The characterization of effects of site and mine water on sediment quality was informed by the water quality assessment of effects, which was based on a quantitative model. Quantitative water balance modelling results provide a high level of confidence for the water quality assessment, but only a medium degree of confidence for the sediment quality assessment because sediment quality predictions are not incorporated into the model. There is some uncertainty associated with predicting the behaviour and fate of various metals and nutrients introduced into freshwater systems. The residual effect to freshwater sediment quality from site and mine contact water was concluded to be **not significant** because the predicted effects were *moderate* in magnitude, localized to the LSA, and assigned a medium degree of confidence (Table 5.5-9).

Table 5.5-9. Summary of Residual Effects and Overall Significance Rating for Freshwater Sediment Quality - Phase 2

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction *(positive, variable, negative)*	**Magnitude** *(negligible, low, moderate, high)*	**Duration** *(short, medium, long)*	**Frequency** *(infrequent, intermittent, continuous)*	**Geographic Extent** *(PDA, LSA, RSA, beyond regional)*	**Reversibility** *(reversible, reversible with effort, irreversible)*	**Probability** *(unlikely, moderate, likely)*	**Significance** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Site Preparation, Construction, and Decommissioning	Variable	Low	Short	Intermittent	LSA	Reversible	Likely	Not Significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not Significant	Medium

Table 5.5-10. Summary of Residual Effects and Overall Significance Rating for Freshwater Sediment Quality - Hope Bay Development

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction *(positive, variable, negative)*	**Magnitude** *(negligible, low, moderate, high)*	**Duration** *(short, medium, long)*	**Frequency** *(infrequent, intermittent, continuous)*	**Geographic Extent** *(PDA, LSA, RSA, beyond regional)*	**Reversibility** *(reversible, reversible with effort, irreversible)*	**Probability** *(unlikely, moderate, likely)*	**Significance** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Site Preparation, Construction, and Decommissioning	Variable	Low	Short	Intermittent	LSA	Reversible	Likely	Not Significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not Significant	Medium

Hope Bay Development Potential Effect

No additional incremental effects from site and mine contact water beyond the effects assessed under the Phase 2 development were identified (Section 5.5.4.2). Therefore, the residual effect to freshwater sediment quality from site and mine contact water for the Hope Bay development was rated as **not significant**, following the same criteria as for the Phase 2 analysis (Table 5.5-10).

5.6 CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when the potential residual effects of the Project affect (i.e., overlap and interact with) the same VEC (in this case, freshwater sediment quality) that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities.

5.6.1 Methodology Overview

5.6.1.1 Approach to Cumulative Effects Assessment

The general methodology for cumulative effects assessment (CEA) is described in Volume 2, Section 4, and focuses on the following activities:

1. Identify the potential for Project-related (Phase 2 and the complete Hope Bay Development) residual effects to interact with residual effects from other human activities and projects within specified assessment boundaries. Key potential residual effects associated with past, existing, and reasonably foreseeable future projects were identified using publicly available information or, where data was unavailable, professional judgment was used (based on previous experience in similar geographical locations) to approximate expected environmental conditions.
2. Identify and predict potential cumulative effects that may occur and implement additional mitigation measures to minimize the potential for cumulative effects.
3. Identify cumulative residual effects after the implementation of mitigation measures.
4. Determine the significance of any cumulative residual effects.

5.6.1.2 Assessment Boundaries

The CEA considers the spatial and temporal extent of Project-related residual effects on freshwater sediment quality combined with the anticipated residual effects from other projects and activities to assist with analyzing the potential for a cumulative effect to occur.

<u>Spatial Boundaries</u>

The spatial boundary for the CEA was the assessment Regional Study Area (RSA; Figure 5.2-2). This study area contains the LSA and was determined to cover the extent of direct and indirect effects of the Project on the freshwater environment.

<u>Temporal Boundaries</u>

The temporal boundaries of the CEA were defined by the timelines for Past, Existing, and Reasonably Forseeable Projects as described in the CEA methodology (Volume 2, Section 4). These timelines were compared to the Project timeline (Section 4.4.3).

5.6.2 Potential Interactions of Residual Effects with Other Projects

The mining industry is the main source of industrial activity in Nunavut, which is being explored for uranium, diamonds, gold and precious metals, base metals, iron, coal, and gemstones. In addition to major mining development projects, other land use activities are also present in the territory and, as required under Section 7.11 of the Project EIS guidelines, were considered for potential interactions with the Project (see Volume 2, Section 4 for more detail).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Hope Bay Project lie within the freshwater assessment RSA. Given that the Project residual effects were confined to the LSA, no cumulative effects to the freshwater sediment quality were predicted.

5.7 TRANSBOUNDARY EFFECTS

The Project EIS guidelines define transboundary effects as those effects linked directly to the activities of the Project inside the NSA, which occur across provincial, territorial, international boundaries or may occur outside of the NSA (NIRB 2012). Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

The non-significant residual effects to freshwater sediment quality were predicted to be restricted to the Phase 2 Project LSA. The LSA lies entirely within Nunavut, and therefore no potential for transboundary effects was identified.

5.8 IMPACT STATEMENT

The assessment of effects from the Project to the freshwater sediment quality VEC considers potential effects grouped into interaction groups. These interaction groups considered Project effects that are related by timing and mitigation and management measures. The following interaction groups are considered as potential effects:

- construction and decommissioning activities;
- site and mine contact water;
- quarries and borrow pits;
- explosives;
- fuels, oils, and PAH;
- treated sewage discharge; and
- dust deposition.

Potential effects are characterized using key indicators and quantitative thresholds as well as experience from the Hope Bay Development. The assessment considers mitigation and management measures already applied in the Hope Bay Development, drawn from guidance documents, and applied in other mining projects in Nunavut and the Northwest Territories.

Quantitative and qualitative analyses were used to predict the effects of the Project on freshwater sediment quality. Residual effects were identified for two interaction groups: site preparation, construction and decommissioning activities from in-water works; and site and mine contact water.

Using the thresholds identified for the key indicators, the residual effects to freshwater sediment quality are concluded to be low to moderate in magnitude and are restricted to the LSA. As a result, the residual effects are rated as Not Significant. No cumulative effects are predicted to occur because the Project freshwater sediment quality residual effects are not predicted to overlap spatially with any other past, existing, or reasonably foreseeable project. Similarly, no transboundary effects are identified because the Project residual effects are predicted to extend only within the LSA that is entirely within Nunavut.

5.9 REFERENCES

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